DEVONIAN BRACHIOPODS AND PELECYPODS OF THE BUCHAN CAVES LIMESTONE, VICTORIA

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Abstract

Brachiopods, pelecypods, sedimentary phases, and paleoecology of the Buchan Caves Limestone and neighbouring equivalent limestones are described. The brachiopods are represented by five genera (three new) and ten species (five new). Pelecypods are represented by ten genera and twelve species of which seven species are new.

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A. Introduction

The presence of a distinctive assemblage of Devonian volcanics overlain by a sequence of richly fossiliferous limestones occurring in the Buchan area of eastern Victoria has been recognized since the middle of the nineteenth century. Howitt (1876, 1878) was the first to closely investigate this sequence and subdivided it into the Snowy River Porphyries and the overlying Buchan limestone. Later (1878) he concluded that the upper part of the Snowy River Porphyries should be included with the overlying limestones and designated these the Lower and Upper Buchan Beds respectively.

No further significant stratigraphic contribution was made until Teichert mapped the Buchan area for the Victorian Mines Department about 1946. He subdivided the limestones and calcareous shales into several formations and members; the lowest and most persistent formation of up to 800 ft. of limestone he termed the Cave Limestone (1948, p. 61). However, the recently set up code of stratigraphic nomenclature for Australia requires that the names of formations be compounded from a lithologic and a geographic name. A slight amplification of the name to Buchan Caves Limestone has been approved by the local stratigraphic committee. The Buchan Caves Limestone is well developed in the Buchan Caves Reserve and this is obviously the source from which Teichert derived the original name he gave to the formation.

Teichert's orginal definition is as follows:

"At the base of the sedimentary series is . . . a sequence of tuffs, agglomerates, grits and sandstones. . . . They are followed conformably by about 600-700 ft. of limestone for which the name Cave Limestone is proposed. This limestone is unfossiliferous (or almost so) in its lower part, but becomes increasingly fossiliferous in its upper two-thirds, the most important fossils being *Campophyllum recessum* Hill and *Spirifer yassensis* de Koninck, with which are associated a rich coral fauna and, in the upper third or so, numerous pelecypods (*Modiomorpha*,

Conocardium, et al.), nautiloids, and ostracodes. . . . The Cave Limestone is overlain by a mudstone-limestone series of somewhat complex stratigraphy and up to 1,800 feet thick. Immediately overlying the limestone are calcareous mudstones with limestone nodules and discontinuous limestone bands, characterized by an abundance of *Chonetes australis* McCoy."

The lower contact of the Buchan Caves Limestone is one of approximate conformity with the upper surface of the Snowy River Volcanics. The best section illustrating the sequence from Snowy River Volcanics into Buchan Caves Limestone is along the west bank of the Murrindal River approximately three-quarters of a mile north of the end of Moon's Road, Buchan, where a thin band of lithified tuff

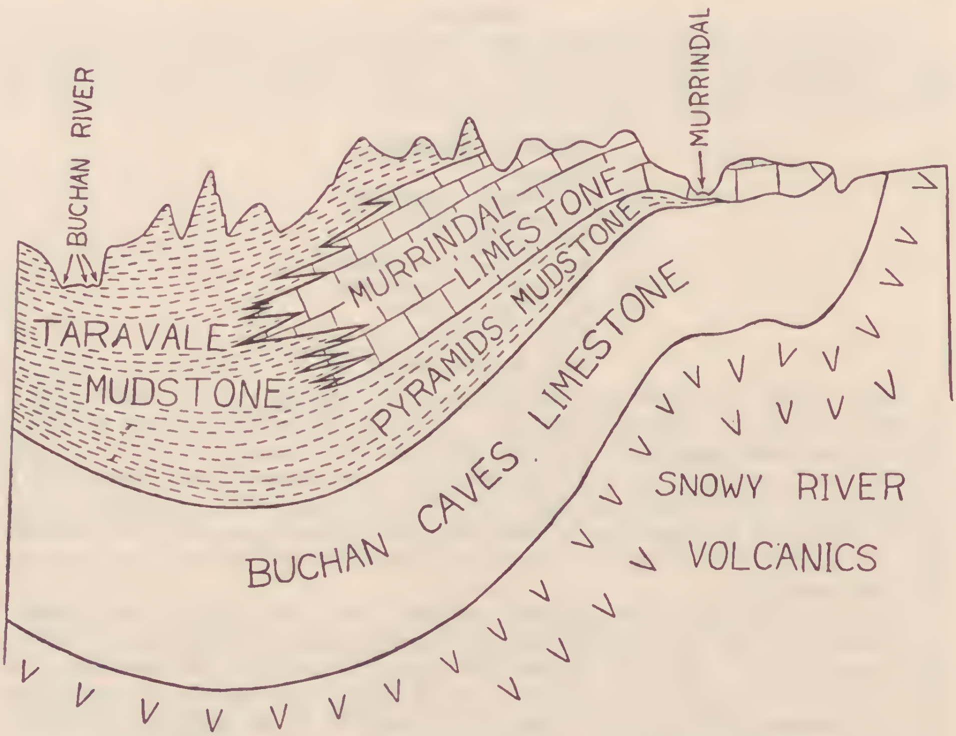


FIG. 1.—Diagrammatic representation of relationship of the Buchan Caves Limestone to underlying and overlying formations.

succeeded by a thin basalt flow rich in magnetite immediately underlies the thin basal grit and impure carbonate rocks of the base of the Buchan Caves Limestone. The upper contact of the Buchan Caves Limestone is generally sharply delineated from the succeeding calcareous mudstones and impure limestones of the Taravale Mudstone and Pyramids Mudstone. The relationship of the Buchan Caves Limestone to the succeeding formations is illustrated by Fig. 1.

Contributions on the paleontology of the Buchan Group have been made by Ripper (1937), Hill (1950), Teichert and Glenister (1952), and Krömmelbein (1954). Ripper described stromatoporoids from five localities in the Buchan area. Three of her localities (Heath's quarry, Citadel Rocks, and "near Hicks'") are in the Buchan Caves Limestone. From these localities she described nine species

and two subspecies distributed over four genera. Krömmelbein (1954) has described fourteen species of ostracodes from the Buchan Caves Limestone. These are distributed over seven genera. Hill (1950) described three species of tetracorals and five species of tabulate corals from the Buchan Caves Limestone. The specimen of *Pseudamplexus ? princeps* Etheridge she included with this fauna is actually from the lower part of the Taravale Mudstone. *Favosites pluteus* Hill, *Gephuropora duni* Etheridge, *Favosites stelliformis* (Chapman), and *Thamnopora angulata* Hill, previously described from higher beds, are now found to occur as well in the Buchan Caves Limestone. In addition three new species yet to be described (of *Acanthophyllum*, *Cystiphylloides*, and *Thamnopora*) have been found in the Buchan Caves Limestone. Teichert and Glenister (1952) described several nautiloid genera from higher beds in the group. Of these genera at least three—*Brachydomoceras*, *Macrodomoceras*, and *Pectinoceras* (at Jackson's Crossing) occur in the Buchan Caves Limestone and its equivalents.

Undescribed groups include foraminifera (particularly in muddy phases), receptaculitida (one solitary specimen of *Receptaculites* from R.S.M. 12), pelmatozoa (stem fragments only), bryozoa (*Stomatopora* and *Proboscina* at Spooner Ck., the Basin), pteropods (*Tentaculites* at J.C. 27), trilobites (a single phacopid pygidium at R.S.M. 78), algae, and gastropods (*Straparolus*, cf. *Oriostoma*, *Anematina*, large *Murchisonia*, *Ostlerina* or *Strophostylus*, indeterminate bellerophontid, and at least two species of *Loxonema*).

The Buchan Group has been regarded as Middle Devonian in age ever since McCoy (1867) correlated it with the "Devonian limestones of the Eifel". This correlation has been supported by recent work by Ripper (1937), Teichert (1948) and Hill (1950). Hill (1950, p. 138) concluded that the coral fauna of the lowest formation, the Buchan Caves Limestone, indicated an "horizon somewhere near the junction between the Emsian and Couvinian, probably Couvinian". Corals she suggests indicate a Couvinian age (i.e. the Acanthophyllids, *Favosites bryani* and *Aulopora conglomerata*) occur low in the formation. And in addition the recognition of *Favosites pluteus*, *Gephuropora duni*, and *Thamnopora angulata* in the Buchan Caves Limestone further weighs the balance in favour of Couvinian rather than Emsian. The correlative significance of the brachiopod fauna will not be dealt with until the brachiopods of the succeeding formations have been described.

Localities mentioned in the text are located on stratigraphic sections represented by the symbol given before the number, and the individual localities specifically referred to are listed at the back of this paper. Symbols used with specimen numbers are as follows: M.D.V. = Geological Museum of the Mines Department of Victoria (collected by Dr. Curt Teichert); N.M.V. = National Museum of Victoria; M.U.G.D. = Melbourne University Geology Department Museum (collected by the author).

Numerous people have contributed assistance and encouragement during this work. Dr. Curt Teichert suggested the study of the brachiopods of the Buchan Group and generously made available his collections, unpublished maps, and report on the Buchan area. Dr. D. E. Thomas of the Mines Department of Victoria arranged for the loan of collections made by Dr. Teichert while employed by that department, and arranged for Fig. 2 to be redrawn by the Mines Department. Mr. E. D. Gill permitted the author to study the type specimens of *Spirifer howitti* housed in the National Museum of Victoria. The manuscript has been read and criticized by Professor E. S. Hills and Dr. O. P. Singleton. Financial assistance came from University research grants for 1953 and 1954 and from a Dafydd

Lewis Research Scholarship awarded by the Trustees of the Dafydd Lewis Trust. Generous hospitality was extended to the author by the McLarty family at Buchan, the McRae family at the Basin, and the Hughes family at Butcher's Ridge. Numerous personal friends have given assistance and advice in the field and laboratory. To all these people the author extends his sincere thanks.

B. Neighbouring Equivalents

The sole contribution of any significance on the neighbouring occurrences of Devonian limestone associated with Snowy River Volcanics is that of Howitt (1876 and 1878). Faunas of the following five occurrences are listed in Table 1, and supplementary notes are included below.

1. *Gillingall Limestone*

Howitt (1876 and 1878) was the first to investigate the occurrence of Middle Devonian limestone at Gillingall on the upper Buchan River. He published three sketch sections through the limestone and neighbouring formations and gave brief qualitative descriptions of the sequences on these sections. He recognized the close relationship between the faunas of the Gillingall Limestone and those of the limestones at Buchan. No further published work has appeared on this locality.

The Gillingall Limestone consists of at least 550 feet of generally dark grey calcarenite with subordinate calcilutite and dolomite occurring on the upper Buchan River about 24 miles by road and 12 miles in a direct line from Buchan. The limestone outlier outcrops in the valleys of Woolshed and Fryingpan Creeks. On the west the limestone is underlain by the Snowy River Volcanics, and is terminated on the east by the Gillingall Fault. Dips are generally of the order of 15° to 25° E. and strike is usually about N. 20° E. An abbreviated stratigraphic section on the east side of Woolshed Creek opposite the old Gillingall homestead, corresponding to Howitt's sketch section 10 (1878, p. 126), is as follows:

Section truncated by Gillingall Fault

21.	Extensively veined stylolitic calcarenite	9′
20.	Moderately fossiliferous dark grey to black calcarenite	51′
19.	*Breviphyllum* biostrome	2′
18.	Algal limestone with abundant *Anematina*	1′
17.	Dark grey calcarenite with occasional *Spinella* and *Breviphyllum*	13′
16.	*Breviphyllum* biostrome	2′
15.	Alternation of medium to fine-grained calcarenite and calcilutite, variably fossiliferous with *Spinella, Buchanathyris, Syringopora, Breviphyllum*, and other fossils	167′
14.	Algal pisolite teeming with *Anematina*	2′
13.	Mid grey, poorly fossiliferous calcarenite	36′
12.	Algal limestone	2′
11.	Dark grey virtually unfossiliferous calcarenite	31′
10.	Pale grey dolomite, calcitic dolomite and dolomitic limestone	33′
9.	Dark grey poorly fossiliferous calcarenite with *Spinella, Buchanathyris, Syringopora*	20′
8.	Pale grey calcitic dolomite	4′
7.	Yellow and grey generally unfossiliferous calcarenite	78′
6.	Silicified rhyolitic tuff	3′
5.	Massive pale grey unfossiliferous calcilutite	24′
4.	Massive mid grey unfossiliferous dolomite	26′
3.	Chocolate-brown tuffaceous limestone	5′
2.	Concealed	31′
1.	Snowy River Volcanics	—
	Total	540′

TABLE 1

	Butcher's Ridge	Gillingall	Mount Murrindal	The Basin	Jackson's Crossing
Actinostroma cf. *compactum* Ripper ..	×				
Actinostroma sp. unident.	×				
Clathrodictyon regulare (Rosen)	×				
Breviphyllum recessum (Hill)	×	×	×	×	×
Acanthophyllum aequiseptatum Hill ..		×			×
Acanthophyllum n. sp.					×
Cystiphylloides n. sp.					×
cf. *Disphyllum speleanum* Hill					×
Metriophyllum sp. indet.					×
Aulopora conglomerata Goldfuss ..				×	×
Favosites pluteus Hill	×				
Favosites bryani Jones	×		×	×	×
Favosites cf. *bryani* Jones		×			
Favosites cf. *stelliformis* (Chapman) ..				×	
Gephuropora duni Etheridge	×				
Roemeria sp.		×		×	×
Syringopora flaccida Hill	×	×	×	×	×
Thamnopora angulata Hill	×				
Thamnopora alterivalis (Chapman) ..	×				
Stomatopora sp.	×			×	
Proboscina sp.				×	
Buchanathyris westoni n. gen., n. sp. ..	×	×	×	×	×
Buchanathyris waratahensis n. sp. ..	×				×
Chonetes australis McCoy				×	×
Chonetes cf. *buchanensis* Gill					×
Chonetes spooneri n. sp.				×	
Spinella buchanensis n. gen., n. sp. ..	×	×	×	×	×
Conocardium howitti n. sp.	×				
Modiomorpha tenuilineata n. sp. ..	×				×
Modiomorpha concentrirugosa n. sp. ..					×
Nuculana insolita n. sp.					×
Schizodus sp.					×
Actinopterella sp. indet.				×	
Anematina sp.	×	×	×		×
Bellerophontid indet.		×		×	
Loxonema spp.	×	×	×	×	×
Murchisonia sp.	×				
Tentaculites sp.					×
Pectinoceras n. sp.					×
Other nautiloids	×	×		×	×
Ostracodes		×			×
Algae	×	×	×	×	×

The close faunal relationship shown by the accompanying table and the almost identical succession signifies contemporaneous deposition of the Gillingall and Buchan Caves Limestones.

2. *Butcher's Ridge Limestone*

Richly fossiliferous limestone occurs at Butcher's Ridge on both sides of the Gelantipy Road just north of the Butcher's Ridge Post Office. The best exposures

are seen in a gully on the east side of the road, but richly fossiliferous outcrops have been exposed in a dozed cutting in Angus Hodge's paddock on the west side of the road. The sequence is fairly similar to those described from other locations but is rather thinner than most. Not more than 300 feet of gently dipping limestone is present resting conformably on the upper surface of the Snowy River Volcanics. The sequence is faulted down on the north against Snowy River Volcanics, and is overlain by Tertiary basalt to the south. In the gully on the east side of the Gelantipy Road rhyolite and agglomerate of the volcanics are succeeded by a thin sequence of unfossiliferous dolomite and dolomitic limestone passing upwards into unfossiliferous calcarenite, calcarenite with jasper, and poorly fossiliferous calcarenite containing *Spinella* and *Buchanathyris*. Then follows richly fossiliferous fine-grained calcarenite with well preserved *Breviphyllum recessum* and *Spinella*. The sequence then becomes less fossiliferous until faulted out except for a short succession where the rock is teeming with *Anematina* and has associated rare *Murchisonia* and *Loxonema*.

Stratigraphically the highest and richest locality is in Angus Hodge's paddock near the entrance gate from the Gelantipy Road. This locality has yielded the stromatoporoids and tabulate corals listed in the accompanying table. The basal dolomitic sequence is thinner here than, for example, at Moon's Road, further south. The brachiopods and pelecypods are generally in an articulated state, and the fauna is much more varied than further south in the Buchan Caves Limestone.

3. *Mount Murrindal Outlier*

For convenience, the outlier of limestone occurring on the old Murrindal-W Tree track about half a mile south of W Tree Creek bridge has been referred to as the Mount Murrindal Outlier. This is quite a normal outlier of Buchan Caves Limestone with the usual basal dolomitic sequence passing upwards into mid-grey and dark grey calcarenites. The fauna is neither rich nor well preserved, but the common forms are the same as those in the Buchan Caves Limestone, and algal pisolite, so characteristic of the Buchan Caves Limestone, occurs here.

4. *Basin Limestone*

The approximate extent of the Basin Limestone is given in Fig. 2. The outcrop, which was first mentioned by Howitt (1876, p. 204), is in the valleys of Basin and Spooner Creeks, and reaches a thickness of about 250 feet. A local occurrence of muddy limestone on Spooner Creek is dealt with in detail in the section on sedimentary phases. An abbreviated stratigraphic section up the east side of McRae's Ridge from the contact of the Snowy River Volcanics and the limestone is as follows:

9.	Moderately fossiliferous mid grey calcarenites with *Spinella*, nautiloids, *Breviphyllum*, *Favosites*	75′
8.	*Spinella* coquina	2′
7.	Moderately fossiliferous mid grey calcarenite with *Spinella*, *Favosites*, *Breviphyllum*	15′
6.	Massive laminated limestone	4′
5.	Stylolitic calcarenite with occasional *Spinella*, *Loxonema* and *Favosites*	38′
4.	Grey calcitic dolomite	40′
3.	Obscured by Blue Bullock Creek alluvium	45′
2.	Poor exposures of pink tuffaceous limestone and yellow calcitic dolomite	15′
1.	Snowy River Volcanics	—
	Total	234′

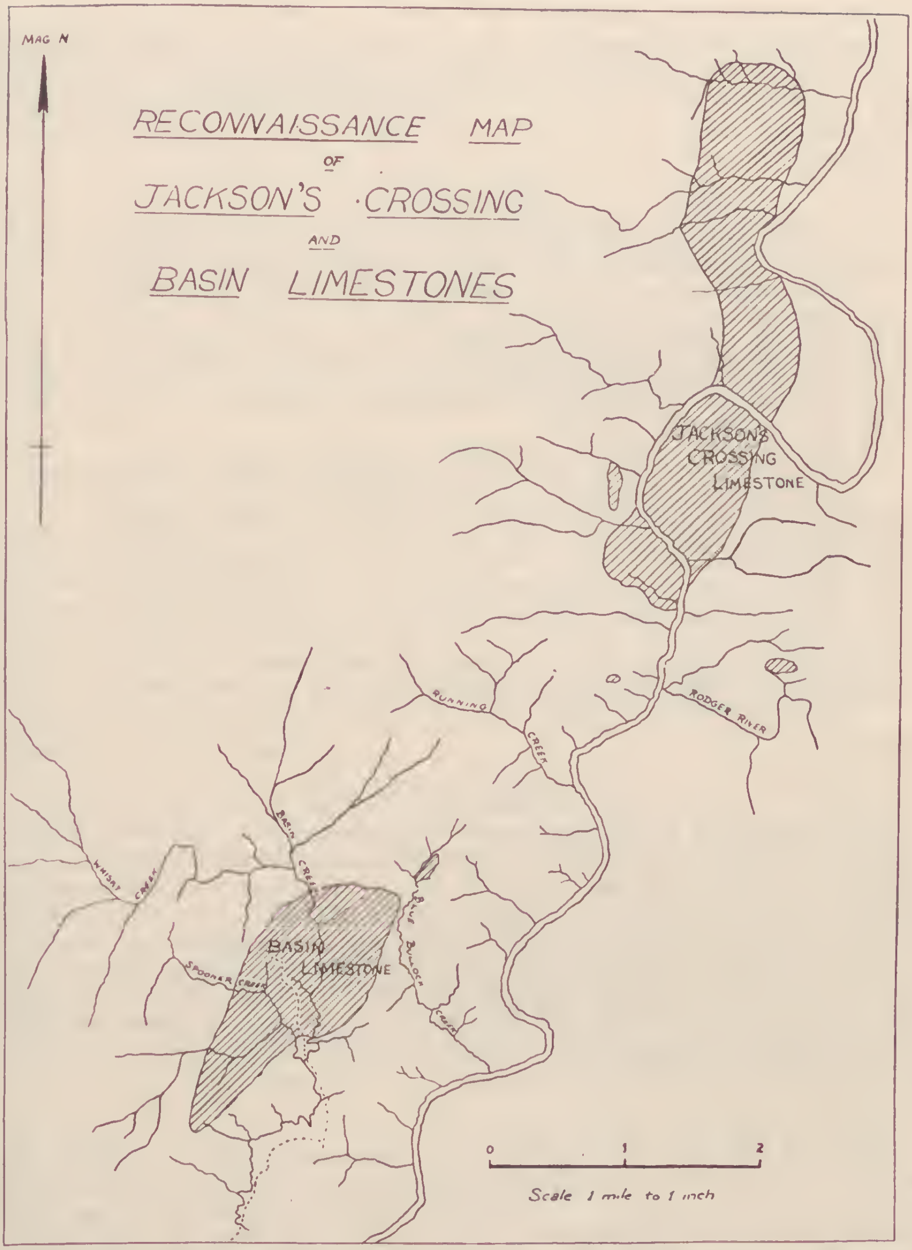


FIG. 2.—Reconnaissance map showing the extent of the Jackson's Crossing Limestone and the Basin Limestone. Some of the information is from unpublished work of W. H. Ferguson.

5. *Jackson's Crossing Limestone*

The extent of the Jackson's Crossing Limestone is shown in Fig. 2. The local muddy phase is dealt with in the section on sedimentary phases. This limestone has a richer fauna than the Buchan Caves Limestone or any of its equivalents. A stratigraphical section from the base of Davidson's Cliff at Jackson's Crossing is as follows:

EROSION SURFACE

15.	Alternation of dark grey to almost black medium-grained calcarenite and calcilutite with occasional *Spinella, Buchanathyris, Loxonema, Anematina* ..	75′
14.	Black calcilutite with common *Spinella*, nautiloids, pelecypods including *Modiomorpha*, ostracodes (very abundant in some bands), and occasional *Buchanathyris*	65′
13.	Pale grey poorly fossiliferous calcilutite	3′
12.	Black calcilutite with *Spinella* and rarer *Loxonema* and *Buchanathyris*, occasionally teeming with ostracodes	90′
11.	Poor outcrops of muddy limestone and ostracodal calcilutite	38′
10.	Algal pisolite with *Anematina*	—
9.	Massive, poorly fossiliferous fine-grained calcarenite	16′
8.	Thin bands of richly fossiliferous limestone alternating with lack of outcrops	—
7.	Yellow mudstone exposed only in rabbit burrows	40′
6.	Richly fossiliferous muddy limestone weathering into rubble on hillside (most of faunal list is from here)	20′
5.	Dark grey poorly fossiliferous calcarenite with rare *Metriophyllum, Spinella*, etc.	33′
4.	Black calcilutite with abundant *Tentaculites*	2′
3.	Dark grey fine-grained calcarenite with *Spinella, Breviphyllum, Favosites bryani*, ostracodes	74′
2.	Sparingly fossiliferous dark grey calcilutite with *Spinella*	30′
1.	Mid grey calcitic dolomite and dolomitic limestone passing vertically into poorly fossiliferous mid grey to dark grey calcarenite	148′
	Total	634′

C. Sedimentary Phases

In the absence of any generally accepted terminology for expressing grain-size in carbonate rocks the terms calcarenite, calcilutite, and calcirudite have been used, utilizing the figures of 2 mm. and 1/16 mm. for the upper and lower limits of calcarenite (lime-sandstone of the English usage). On DeFord's (1946) scale the Buchan calcarenites correspond to his mesograined grain-size, and the calcilutites are micrograined and cryptograined. The terms dolomite, calcitic dolomite, and dolomitic limestone are used in the sense of Pettijohn (1949). With the exception of the basal dolomitic sequence dealt with below at 2, all the succeeding calcarenites and calcilutites are limestones (i.e. composed almost entirely of calcite) and this fact is implied wherever these terms are used in this paper.

1. *Basal Grits, Impure Limestones, etc.*

The basal few feet of the Buchan Caves Limestone provide an excellent illustration of variation in equivalent beds, depending on the local conditions under which deposition has occurred. No difficulty is had in delineating the base of the Buchan Caves Limestone where it is exposed. In the space of a few feet the porphyritic rhyodacite of the Snowy River Volcanics gives way to lithified tuff and basalt and the Buchan Caves Limestone commences with a conglomerate, grit or muddy limestone. The conglomerates contain pebbles of rhyodacite, tuff and basalt (now completely spheroidally weathered) in a matrix of large quartz grains and

clay. The coarse friable grit at the base of the Moon's Road section (M.Rd. 1) shows large subangular quartz grains in a clay matrix. The quartz grains have undergone so little rounding that a minimum of transportation is indicated. The components of the localized conglomerates, grits and siltstones have clearly been derived from the Snowy River Volcanics.

Other localized components of the basal few feet of the Buchan Caves Limestone such as muddy limestones and dolomites, calcareous siltstones and mudstones, represent a combination of sediments partly derived from neighbouring terrestrial sources, and partly derived by direct chemical precipitation from sea water. Local intercalcations of tuffaceous material may be found, as for example at Gillingall (Gill.3), but these cannot be traced or correlated over any distance. These rare intercalcations can generally be described as tuffaceous limestones compounded of calcium carbonate and material derived from erosion of previously deposited tuffs. True tuffs are extremely rare and insignificant, emphasing the hiatus between the volcanic activity and the inception of carbonate sedimentation. There is no transition zone as such.

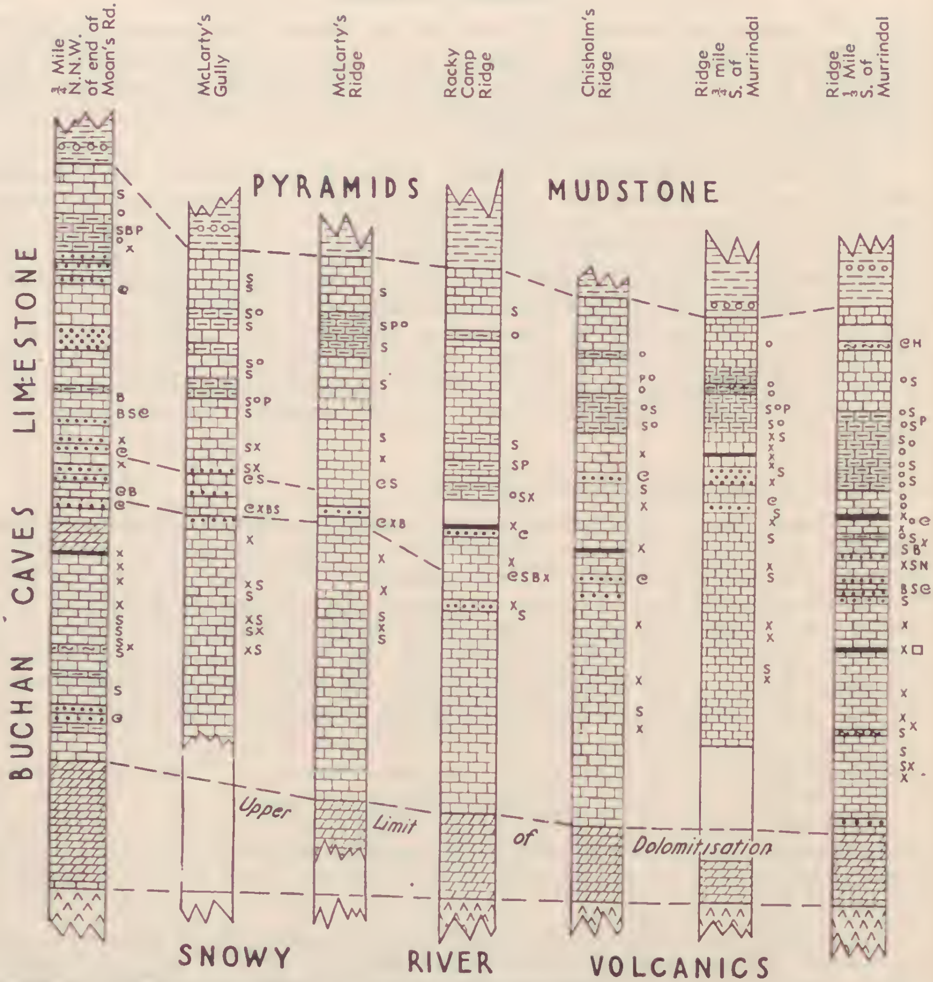
2. *Dolomite and Dolomitic Limestone*

The lower part of the Buchan Caves Limestone is characteristically dolomitic wherever it outcrops. The Murrindal River runs approximately along the conformable junction of the Buchan Caves Limestone with the underlying Snowy River Volcanics so that the basal dolomitic zone can be traced down the Murrindal valley from north of Murrindal almost to the Snowy River. Dolomite, equivalent in age, occurs at the base of the Gillingall Limestone, the Basin Limestone, the Jackson's Crossing Limestone, and at Mount Murrindal. All these dolomites grade upwards through dolomitic limestone into undolomitized fossiliferous mid grey calcarenite.

These dolomites are light grey to mid grey in colour, and generally vary from sublithographic dolomite to the texture of coarse calcarenite. Calcirudite grain size is rarely reached, but sugary dolomites with grain size up to 1 mm. in diameter are not altogether uncommon. Rarely, pinkish and greenish tints occur in extremely fine-grained dolomites breaking with a subconchoidal fracture. Such pink and green tints are best seen in the lower part of the Jackson's Crossing Limestone section at Davidson's Cliff.

An average sample of mid grey dolomite in thin section shows anhedral crystals 0·1 to 0·5 mm. in diameter, mutually accommodated along irregular boundaries. None of the thin sections cut show recognizable traces of fossils, although very rare poorly preserved specimens of *Spinella*, *Syringopora flaccida* and algae have been collected in the basal 50 feet in places. The *Spinella* shells are occasionally in the form of cavities lined by minute calcite crystals, and the *Syringopora flaccida* colonies are generally infilled by very coarsely crystalline calcite. Some beds are characterized by leached cavities which have subsequently been partially or completely infilled by clear crystalline calcite. These cavities may be up to 3 cm. across but are generally about 5 to 10 mm. wide. Their outline is highly variable, often jagged, indicating that they have not been derived by leaching of fossils.

Some of the finer-grained dolomites are characteristically laminated, the laminae being marked by slight differences in texture and colour. For instance some of the dolomite from near the base of the Gillingall Limestone shows broad, pale, rather poorly defined laminae alternating with finer, darker laminae having a higher organic matter content.



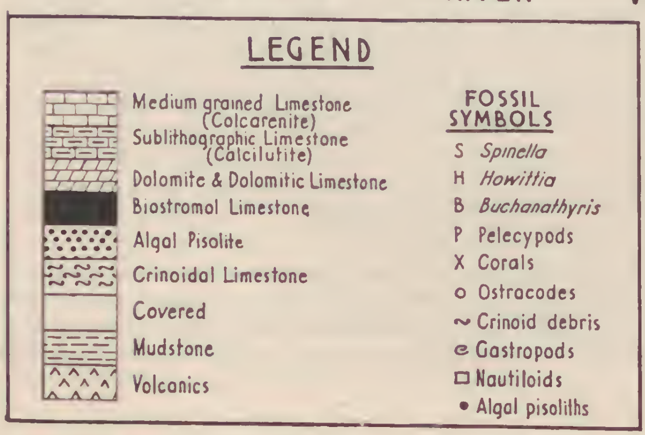


Fig. 3.—Stratigraphic sections of the Buchan Caves Limestone along the west bank of the Murrindal River showing lithology and occurrence of common fossils. Features of note are the basal dolomitic sequence, the patchy distribution of the algal pisolith phase (although more common in the south), limitation of calcilutite to the upper part of the sequence, patchy distribution of the biostromes, and the two distinctive bands of gastropods and entire brachiopods infilled by calcite. The *Spinellas* are almost omnipresent, corals tend to be limited to the calcarenites lower in the sequence, and ostracodes and pelecypods are more characteristic of the calcilutites of the upper part of the formation. The distances apart of the various sections are as follows, from the most southerly section N. of Moon's Rd. to the Murrindal sections: 0·3, 0·2, 0·45, 1·3, 0·7, 0·4 miles respectively. Thickness of sections are on a scale of 1″ equals 200′.

Cloud and Barnes (1948, p. 92) have suggested that aragonitic muds such as those occurring in restricted parts of the Bahamas may be especially susceptible to dolomitization. To adduce that the dolomitized rocks of the Buchan Caves Limestone were originally aragonitic muds it must be envisaged that the resultant grain size has been enormously increased during dolomitization. This would be feasible were it not for the fact that the dolomitic sequence grades vertically into undolomitized calcarenites of equal or even greater grain size, indicating that if there has been a general change in grain size it has not been associated with the process of dolomitization.

The origin of the dolomite is clearly due to diagenetic replacement, for originally calcareous shells have been substituted by a crystalline mosaic of dolomite, or have been left as leached out cavities. The dolomitized sequence is limited to the base of the formation and as a consequence must bear some relationship to the initial stages of sedimentation or to the underlying Snowy River Volcanics. The virtual cessation of igneous activity before the commencement of sedimentation rules out igneous activity as being responsible. The contact between Buchan Caves Limestone and Snowy River Volcanics may have provided a favourable surface along which magnesium-enriched solutions could permeate the base of the Buchan Caves Limestone and produce a basal dolomitic zone. This interpretation of origin would leave the source of these dolomitizing solutions as unknown. The traditional view that dolomitization is a process associated with shallow, probably hypersaline, conditions agrees well as it is only the initial sediments that have been dolomitized.

3. *Calcarenite* (*Lime-Sandstone*) (Pl. V, figs. 1 and 2)

Fine-grained fossiliferous calcarenite is quantitatively the most important single sedimentary phase of the Buchan Caves Limestone. By decrease in grain size and proportion of detrital calcite the calcarenites pass imperceptibly into calcilutites. Increase of algal pisoliths causes lateral change from calcarenite to algal pisolite, the proportion of algal pisoliths generally being seen to increase in a southerly direction where this change can be observed. The lower sequence of dolomites of the Buchan Caves Limestone passes upwards imperceptibly through dolomitic limestone into calcarenite and algal pisolites.

The most common type of calcarenite consists of a variable amount of dark generally well-rounded grains of detrital calcite and bioclastic debris cemented by clear calcite. The detrital calcite grains are remarkably uniform in size and roundness in some beds but show great variation of shape and size in other beds, indicating varying degrees of sorting and abrasion during transport.

Bioclastic debris is often hard to identify but most commonly consists of broken shells of ostracodes, brachiopods, rugose and tabulate corals, and algal colonies. At some localities where algae are more frequent the brachiopod shells and fragments are often seen to be reticulated by penetrative algae. Minor recognizable contributions are from gastropods (particularly *Anematina*), crinoids and pelecypods. Entire rugose and tabulate corals, stromatoporoids, brachiopods, pelecypods, gastropods, nautiloids, ostracodes and algae (discrete, penetrative and enveloping types) occur at various localities. Corals, brachiopods and ostracodes far outweigh all other organisms in the proportion of skeletal material contributed. Locally the proportion of brachiopod shells becomes so great as to result in coquinoid limestones. The brachiopod shells retain their fibrous structure, whereas the shells of gastropods (*Anematina*) have developed a saccharoidal texture from crystallization of anhedral calcite grains.

The bioclastic debris and detrital calcite are cemented by ragged anhedra of clear crystalline calcite or dark, very fine-grained calcite with a high proportion of interstitial organic matter. Wherever the calcite cement is coarsely crystalline it is often seen to pass laterally into finely felted calcite crystals usually of the order of ·05 mm. width but sometimes less than ·01 mm. wide. By decrease in proportion of bioclastic debris and detrital calcite grains and decrease in grain size of interstitial calcite the calcarenites pass imperceptibly into calcilutites. It is possible that where the interstices have a coarse and fine grade of calcite the coarsely crystalline calcite has been derived by recrystallization of the previously crystallized fine felting of calcite crystals. The original material filling the interstices between the bioclastic debris, detrital calcite grains and fossils may have been a lime mud or, more probably, a very fine lime sand perhaps resembling in grain size the finest interstitial material now visible. If recrystallization has occurred it is quite likely that some of the almost unfossiliferous calcarenites may have been originally deposited as lime muds. The pinkish grey calcarenite at M.Rd. 43 (Pl. V, fig. 1) has coarse ragged interlocking clear calcite crystals which cannot be of detrital origin and must have resulted from recrystallization.

Non-calcareous components are rather rare and, except for bitumen, have not been identified in any of the sections cut. However, solution of calcarenite in dilute acid generally leaves a small residue consisting mainly of organic matter and considerably smaller amounts of limonite, tiny ragged sand grains and fine mud. Pinkish limestones yield a much greater proportion of limonite, but part of this at least is due to concentration in cracks as a result of weathering. The proportion of organic matter increases with darkening of colour of the calcarenite. The organic matter is mainly carbon, but solution of almost black calcarenites occasionally yields an oily scum on the surface from release of interstitial oil by solution of the limestone. Minute vughs up to 1 mm. across have been found filled with bituminous material which is released on solution of the limestone, and can be dissolved up in mineral turpentine. However, the percentage of organic matter was not greater than 0·4 per cent by weight in the darkest calcarenite so far dissolved up, and most of this percentage was due to carbon rather than to hydrocarbon soluble in turpentine. Much greater percentages of organic matter are found in some of the black calcilutites discussed later.

4. *Coquina and Coquinoid Limestone*

The fossiliferous calcarenites and calcilutites of the Buchan Caves Limestone occasionally become so crowded with remains of *Spinella* that coquinas result. Paired valves are very rare and transportation effects may be so pronounced that slabs covered by *Spinella* shells may have over 70 per cent of a particular valve. These disarticulated valves often show a strong tendency to preferred orientation of their beaks in three directions, mutually at right angles. These results are interpreted in the later section on palaeoecology.

Two particularly distinctive bands of coquinoid limestone composed mainly of entire articulated brachiopods (*Buchanathyris* and *Spinella*) and large gastropods (mainly *Loxonema*) can be traced for over one mile in the middle Buchan Caves Limestone. These bands are seen in the sections as follows: M.Rd. 68 and 64; M.G. 14 and 16. The paired valves are generally infilled by clear crystalline calcite and indicate quieter conditions of sedimentation than were usual during deposition of most of the Buchan Caves Limestone.

5. *Calcilutite* (*Lime-Mudstone*) (Pl. V, fig. 3)

Dark grey to almost black calcilutite is the most important sedimentary phase of the uppermost third of the Buchan Caves Limestone. The calcilutites are generally highly fossiliferous, containing abundant *Spinella* and ostracodes and less abundant pelecypods (*Modiomorpha*, *Nuculana*), nautiloids and gastropods. Corals, stromatoporoids, crinoids, and algal pisoliths are notably absent or very rare. Very local thin bands have such a high content of organic matter that they correspond to a calcareous black shale. Solution of black calcilutite often results in copious evolution of hydrogen sulphide and possibly of some gaseous hydrocarbons. Traces of hydrocarbons have been noted floating on the surface after solution of limestone samples in dilute acid and have been recovered in organic solvent.

Generally the groundmass is so fine-grained that little information can be obtained from thin sections. However, abrupt textural changes often occur and extremely fine calcilutite may pass abruptly into limestone composed of fragmentary ostracode carapaces and *Spinella* shells cemented by calcilutite. Generally the calcilutites are unlaminated but may occasionally in section show lamination of darker and lighter bands, the poorly defined darker bands having a higher percentage of organic matter than the lighter bands.

The calcilutites grade into fine calcarenites occurring at the top of the Buchan Caves Limestone. This restricted zone is characterized by an increase in variety of life forms. Occasional thin bands of crinoidal limestone and the occurrence of rare *Conocardium*, trilobite, bryozoan, rhynchonellid and tabulate coral remains indicate a reversion to better aerated conditions, particularly in the north of the area.

6. *Ostracodal Limestone*

Ostracodes often made significant contributions as rock builders at several horizons of the upper part of the Buchan Caves Limestone, particularly in the northern part of the area. They occur in various types of matrix but are most common and characteristic of black calcilutite. Occasionally ostracodes are so common that the rock takes on a friable texture as at Jackson's Crossing locality 43.

7. *Muddy Limestones and Calcareous Mudstones*

Impure argillaceous limestones and calcareous mudstones are a rare and insignificant sedimentary phase of the Buchan Caves Limestone. Only three occurrences of any extent are known in the Buchan and neighbouring areas, and all of these are equivalent to some part of the middle of the Buchan Caves Limestone.

(a) *Cameron Mudstone Member*. The largest occurrence of muddy limestone and calcareous mudstone outcrops in a road cutting on the Buchan-Orbost road on the Orbost side of the first hairpin bend approximately one mile east of Back Creek bridge (in allot. 25 of D, H. Cameron; County Plan 1920). The underlying mid grey to dark grey limestones are richly fossiliferous and stylolitic and contain the following fossils: *Gephuropora duni*, *Favosites bryani*, *Breviphyllum recessum*, *Acanthophyllum*, *Thamnopora angulata*, stromatoporoids, *Spinella*, *Buchanathyris westoni* and large nautiloids up to one foot long. Rarer elements include *Loxonema* and pelmatozoan debris. With increase of argillaceous material the limestone becomes full of *Chonetes australis* with occasional *Spinella* and rare *Buchanathyris westoni*. The impure limestone passes rapidly into yellowish mudstone with occasional nodular bands and occasional thin bands from which large specimens of *Spinella*, *Buchanathyris westoni* and *Buchanathyris waratahensis* can be collected.

(b) *Spooner Creek* (*Basin Limestone*). A similar occurrence of muddy limestone and yellow calcareous mudstone occurs in the Basin Limestone outcropping in Spooner Creek approximately a quarter of a mile downstream from the western junction of the Snowy River Volcanics and the Basin Limestone and due south from Don McRae's homestead. The occurrence is more richly fossiliferous than the Cameron Mudstone Member of the Buchan Caves Limestone. *Chonetes australis* and *Spinella* are particularly characteristic, but other fossils include *Chonetes spooneri, Buchanathyris westoni, Actinopterella* sp.ind., and the bryozoa *Stomatopora* and *Proboscina.*

(c) *Jackson's Crossing Limestone.* Richly fossiliferous muddy limestone occurs in the Jackson's Crossing Limestone at J.C. 32. Fossils weathering out into the soil include *Spinella, Buchanathyris westoni, B. waratahensis, Chonetes australis, C. buchanensis, Pectinoceras,* and *Breviphyllum recessum.* The muddy limestone becomes decreasingly fossiliferous as it passes upwards into the yellow mudstone at J.C. 34 and the impure limestone at J.C. 35 which weather into surface nodules. There is approximately 80 ft. of calcareous mudstone and impure limestone from which fossils weather out into the soil.

8. *Algal Pisolite and Algal Limestone* (Pl. V, fig. 6)

Undolomitized algal pisolites occur at many horizons of the Buchan Caves Limestone, are locally very abundant, and form an appreciable proportion of the rock. The individual pisoliths range from 1·5 to 9 mm. in diameter, the largest observed pisolith being 12 mm. across. The pisoliths show considerable variation in shape, some being spherical while others may show re-entrants and nodes on the surface.

Pisoliths from the same band are remarkably uniform in size and shape, probably as a result of sorting or uniform conditions of growth. The pisoliths are characteristically associated with the small narrowly phaneromphalous gastropod *Anematina.* These gastropods average 6 to 7 mm. in length and are the most common nuclei of the pisoliths. Less commonly fossil fragments, particularly broken pieces of *Spinella* shells, are found as nuclei, and rare cases have been noted of particularly large pisoliths enveloping entire specimens of *Buchanathyris.*

Naturally weathered and polished specimens of algal pisolite show pronounced concentric structure of the individual pisoliths, but thin sections reveal that each pisolith is a composite algal colony showing definite growth zones. This structure is unlike that described for the classic dolomitized pisolites of the Guadalupe Mountains reef complex. The concentric structure of these Permian pisoliths is caused by minute lighter and darker laminations (0·01 to 0·05 mm. thick) of very fine anhedral crystalline dolomite and calcite (Newell *et al.* 1953, p. 118). The lack of definite algal structure has led to considerable disagreement as to origin (e.g. Ruedemann, 1929; Pia, 1940; Johnson, 1942). Dolomitization has evidently obliterated practically all semblance of original structure, so that most of the arguments advanced were speculative.

The earliest investigator, Ruedemann (1929, pp. 1079-1080), suggested they were remains of "coralline algae" because of their "microscopic nature". Coralline algae have been recognized as present in sectioned pisoliths from the Buchan Caves Limestone but none of the pisoliths so far investigated have rhodophyta composing the bulk of the pisoliths. The pisoliths consist of irregular dusty "spongy tissue" perforated by regular tubes infilled by relatively clear calcite and irregular "holes" similarly infilled by calcite. The tubes are of two sizes, the larger having a diameter

of 0·10 to 0·15 mm., and the smaller a diameter of 0·02 to 0·035 mm. with well-defined walls approximately 0·005 mm. and 0·02 mm. thick respectively. The irregular holes are without clearly defined boundaries and correspond to parts of the algal mass which were uncalcified, the part occupied by calcified algae being now seen as the spongy layers of "algal dust". The "algal dust" is clearly differentiated from the coarsely crystalline calcite occupying the space between the pisoliths, adding further support to the contention that it is of organic origin.

Solenoporaceae occasionally contribute to the algal complex of some pisoliths, but boundaries with the "algal dust" are rarely clearly defined. Three types of solenoporoid algae have been recognized, the most common being a type similar to *Solenopora centurionis* Pia. An uncommon form with cells of polygonal cross-section 0·05 mm. across has been observed encrusting part of the inner walls of *Anematina* specimens forming the nuclei for pisoliths.

The two sizes of tubes penetrating the "spongy tissue" obviously belong to different algae because of their uniformity of size and the fact that algal pisoliths often have one or the other and not necessarily both types of tubes. It is interesting to note that the sizes of the two types of tubes correspond remarkably well with the sizes of tubes of the two algal genera *Rothpletzella* and *Wetherdella* found by Wood (1949) to occur as symbiotic intergrowths in "*Sphaerocodium*". The major difference in the two occurrences is that each of the forms described by Wood occurs as a tightly tangled coil enveloping a foreign body. The tubes described above may be found as a tightly packed mass or as stray tubes wandering through the "spongy tissue", although the smaller type of tube is more often found in tightly packed masses than the larger type. Neither type corresponds to a described form of Palaeozoic alga, although the nearest comparison is with the two Silurian forms mentioned above.

The relative proportions of the different types of algae found in any particular pisolith are highly variable. The spongy tissue is always present and generally the finer of the two series of tubes can be identified, but quite often no trace of the larger tubes or the solenoporoid algae can be found. The overall structure resembles that frequently described for the hazy and much-abused genus *Sphaerocodium* which, as Wood (1949, p. 21) concludes, is well worthy of suppression as being almost meaningless. Chapman (1917; 1920, p. 175) described under the name of *Sphaerocodium gippslandicum* a Devonian form without relation to previously described forms referred to "*Sphaerocodium*". Examination of Chapman's figure (Pl. XVI, fig. 1) reveals that the cells are certainly not "ovoid or short cylindrical" as he states but are almost certainly long, slender, of uniform width, and are irregular polygonal to hexagonal in cross-section. The section he illustrates is cut in such a fashion that it runs generally sub-parallel to the slender slightly sinuous cells. This accounts for convergence of walls and his misinterpretation that the cells were "ovoid or short cylindrical". The plane of the section becomes more transverse in the lower right-hand corner of the figure, and it is here that the polygonal cross-sections are clearly shown. The conclusion to be drawn is that *Sphaerocodium gippslandicum* Chapman belongs to a totally different algal class from that to which Chapman would have assigned it. It is a coralline alga and should be referred to the genus *Solenopora* Dybowski, 1877, with which it agrees in all aspects except that the cell width (0·15 mm.) is somewhat larger than usual for *Solenopora*, but not abnormally large.

The proportion of algal pisolite increases southwards from Murrindal as the proportion of coralline limestone decreases. The pisolites then fade out again towards

East Buchan with the increase of dolomite. The pisolites are generally associated with the lime sand (calcarenite) phase and not with the lime mud (calcilutite) phase. These facts indicate rather restricted ecological conditions for formation of algal pisolites.

9. *Stromatoporoid Bioherms*

Unlike the Murrindal Limestone, the Buchan Caves Limestone is almost devoid of biohermal accumulations. Teichert mentions two cases of bioherm-like structures, one occurring near the Lane homestead, the other at Heath's quarry near the southern limit of the Buchan Caves Limestone where it is faulted down against Lower Devonian sandstones. Of these two occurrences only the latter has been investigated in any detail.

Heath's bioherm probably occurs at the top of the Buchan Caves Limestone as it has been mapped by Teichert. It is underlain to the east by almost black calcilutite and fine-grained calcarenite bearing *Breviphyllum recessum* and *Spinella buchanensis*, but is separated from this sequence by a wide zone without outcrops and so could possibly belong to the Taravale Mudstone which immediately overlies it and outcrops in the road cutting leading from the quarry. The bioherm passes rapidly upwards through impure limestone and intercalated shales into the typical calcareous shales and mudstones of the Taravale mudstone. These sediments dip steeply westwards, the high angle being probably partly due to differential compaction of the calcareous muds surrounding the solid bioherm (Terzaghi, 1940).

Heath's bioherm extends several hundred yards laterally and is composed of pale grey undolomitized limestone almost entirely made up of stromatoporoid colonies with less significant contributions from rugose and tabulate corals (*Acanthophyllum, Xystriphyllum, Favosites, Gephuropora*, and *Thamnopora*), and algae (*Solenopora* particularly). Interspaces are filled by calcarenite and crinoidal debris. Brachiopods, bryozoa, and molluscs are apparently absent from the reef. Stromatoporoids far outbulk all other forms and two species of *Actinostroma* (*A. compactum* and *A. stellulatum* var. *distans*) are by far the most important of the stromatoporoids. Other less common stromatoporoids include *Actinostroma contortum, Clathrodictyon regulare, C. convictum, Stromatoporella granulata, Stromatopora concentrica, S. colliculata*, and *Hermatostroma episcopale*, the last of these being occasionally common in patches. Some patches of limestone are friable and the stromatoporoid and algal colonies break out on crumbling in the hand.

10. *Coral Biostromes*

Large coral biostromes are uncommon in the Buchan Caves Limestone, but any complete section through the sequence usually strikes at least one small biostrome teeming with *Breviphyllum recessum* corallites and occasional heads of *Favosites bryani, F. pluteus*, or *Gephuropora duni*. Stray biostromal patches in the upper part of the sequence are without heads of tabulate corals. Other corals found rarely associated with the *Breviphyllum* biostromes are *Disphyllum speleanum* and *Acanthophyllum aequiseptatum*. These biostromal patches are usually local developments in otherwise richly fossiliferous coral horizons.

11. *Laminated Limestones* (Pl. V, fig. 5)

Finely laminated limestones have been collected from the Buchan Caves Limestone and all of its neighbouring equivalent formations. Slight colour and textural differences causing lamination are frequently overlooked but many examples of striking colour and textural differences occur.

Some of the pale grey dolomite from near the base of the Gillingall Limestone shows pale grey bands up to an inch thick alternating with darker bands composed of numerous fine dark laminations. The colour differences are due to a higher proportion of organic matter in the darker bands but no definite explanation can be adduced to explain their origin.

Excellent examples of laminated limestone have been collected from East Buchan (600 yards NNE. of Back Creek bridge, along the Buchan-Orbost road) and from Jackson's Crossing (J.C. 39). Both occurrences show pronounced colour banding, the laminae in the latter being an alternation of dark grey with yellow laminae. The darker laminae contain abundant small algal pisoliths, the size of individual pisoliths varying from band to band but averaging 1 to 2 mm. diameter. Occasional larger pisoliths up to 6 mm. diameter may be seen enveloping foreign nuclei. The yellow bands consist of much finer flocculent laminae and curve over the larger pisoliths of the darker bands. The thickness of light and dark major units are quite variable. Graded bedding has not been recognized. All examples of apparent graded bedding have been shown on closer investigation to be too flocculent and to resemble stromatolite structure too closely to be identified as graded bedding.

12. *Tuffs and Ash Beds* (Pl. V, fig. 4)

The quantitative importance of volcanic rocks in the lower part of the Buchan Group has been overstressed in the past. True tuffs are very rare, and when they do occur they are always confined to the base of the Buchan Caves Limestone. No tuffs have been recognized in any of the stratigraphic sections illustrated in Fig. 3 except for a lithified tuff at the top of the Snowy River Volcanics in the Moon's Rd. section. This tuff was laid down before the inception of carbonate sedimentation. Rare tuffs contribute insignificantly in the East Buchan area, and a prominent 3 ft. band of silicified rhyolitic tuff outcrops low in the Gillingall Limestone (Gill. 6).

D. Paleoecology

In view of the general dearth of useful comparative data on ecology of living forms and lack of agreement as to the conditions of deposition of various sediments, no extended analysis of the paleoecology can be given. The following notes are offered as a tentative reconstruction of some aspects of the environmental history of the Buchan Caves Limestone.

The low proportion of insoluble clastics in an average sample of the Buchan Caves Limestone suggests that the carbonates accumulated on a shelf area with a neighbouring landmass of subdued relief providing very little insoluble clastic material.

The nature of the faunal succession indicates a gradual increase of basin depth from very shallow conditions poorly suited to life to more favourable conditions. The basal dolomitic sequence containing very few fossils is succeeded by calcarenites having generally poor faunas of rugose and tabulate corals, brachiopods and gastropods. Further up the sequence the faunas become richer and more diversified, the calcarenites are succeeded by black calcilutites with high proportion of organic matter, the corals disappear, and pelecypods and ostracodes come in. The gastropods tend to be thick-shelled and associated with shallow water sedimentary phases such as the algal pisolites, whereas the thin-shelled pelecypods tend to be restricted to the deeper, more stagnant conditions higher in the sequence. One of these pelecypods, *Nuculana*, ranges from 80 to 120 fathoms in present seas (Nomura and Hatai, 1936).

There is little evidence to suggest extreme climatic conditions. There is a complete absence of glacial phenomena or evaporite deposits. Dolomitization is generally associated with warmer conditions, but the process is so imperfectly known that temperature inference is unwarranted. The corals include potential bioherm building forms, but are unrelated to living corals and cannot be used with certainty to indicate warmer conditions. Similarly none of the brachiopods, pelecypods, or ostracodes appear to be particularly indicative of climate.

The limited number of represented classes suggests some degree of abnormal salinity. Echinoderms and bryozoa, characteristically stenohaline groups, are almost entirely absent. The frequency of beds containing predominantly one species or entirely composed of one species (usually *Spinella* or ostracodes) supports the contention of an abnormal salinity. Modern cephalopods are extremely sensitive to reduced salinity, so the presence of cephalopods in many horizons of the Buchan Caves Limestone indicates that any abnormality of salinity was more likely to be of increased rather then decreased salinity.

Agitation by wave or current action has been a potent agent in the destruction of biocoenosis, disrupting the benthos, and scattering and sorting its various components throughout most of the sedimentary history of the Buchan Caves Limestone. For example, three slabs of black calcilutite from approximately 600 ft. above the base of the Buchan Caves Limestone on the ridge two-thirds of a mile south of Murrindal gave the following results for shells of *Spinella*:

Slab	No. Pedicle Valves	No. Brachial Valves	% Pedicle Valves
1	28	7	80%
2	9	12	43%
3	6	2	75%

Slab 2, with the lowest degree of sorting, was the only one to show an articulated shell. This result is typical of the degree of disarticulation and sorting of *Spinella* valves in the Buchan Caves Limestone. Shells of *Modiomorpha* and other pelecypods (except *Conocardium*) are likewise virtually always found in a disarticulated state whereas *Buchanathyris* shells are usually in an articulated state, testifying to their strong, well-locking hinge teeth. Beds composed predominantly of shell detritus further emphasize the smashing and abrasion which has gone on.

Further evidence of current activity is seen in the alignment of linear fossils or fragments. On rotation by currents, cylindrical shells are aligned parallel to the wave front, whilst conical forms become aligned pointing downstream. The orientation varies with current direction and so can furnish important paleogeographic results if treated with discretion. Classic results have been obtained by Ruedemann (1897, 1898) on graptolites. Orthoconic cephalopods are so rarely concentrated that no attempt has been made to record their alignments, but the ever-present *Spinella* provided abundant material. The disarticulated valves lie with their body cavity downwards and often show a strong tendency to preferred orientation of their cardinal margins in two directions and of their beaks in three directions. A possible interpretation is that a current impinging on the palintrope would tend to orientate the shell so as to align the cardinal margin with the direction of the current, so that in effect the beak would point at right angles to the current direction. Shells with their beaks pointing in the same direction as the passing current would be least affected, so that it would be more likely for shells to have their beaks pointing

at right angles to the current direction or in the same direction as the current than to be pointing towards it. Interpretation of the rosette (Fig. 4) according to these principles implies current action from the west. The pronounced development of

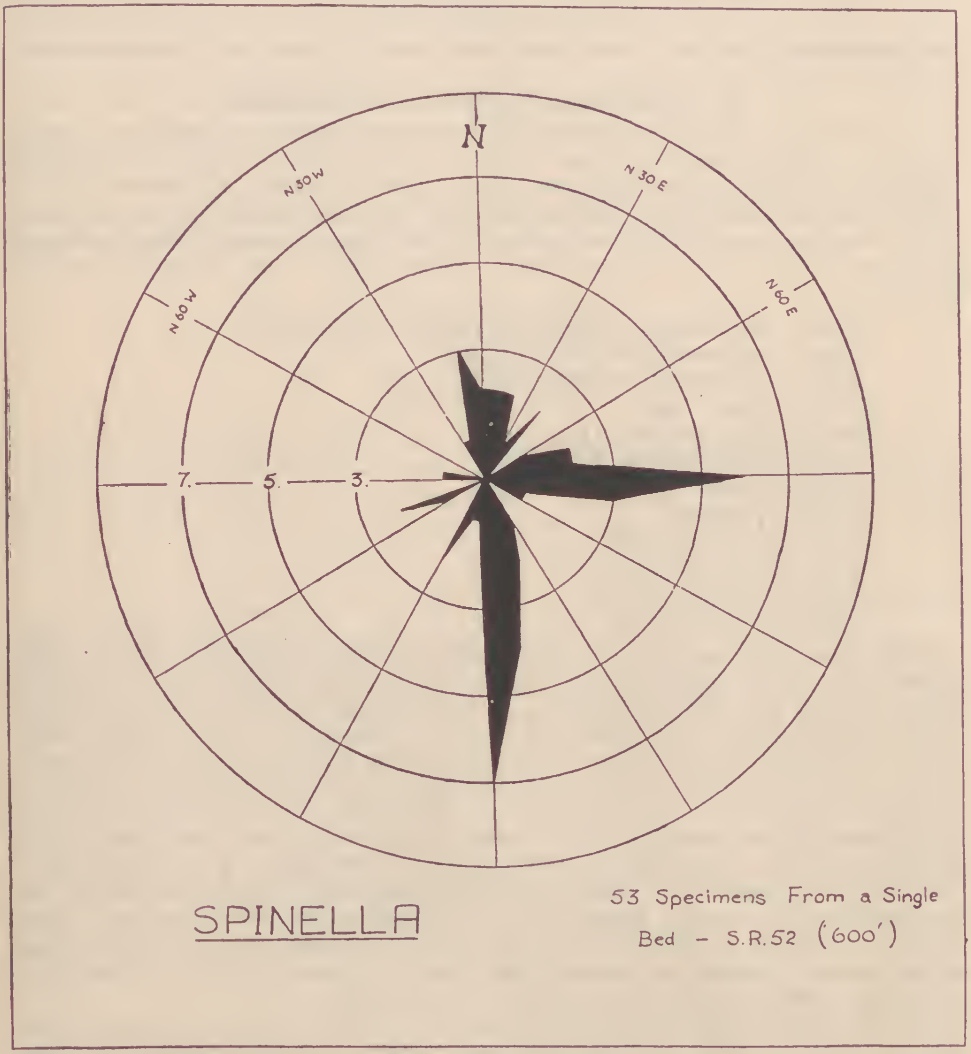


Fig. 4.—Orientation of beaks of 53 specimens of *Spinella buchanensis* showing preferred orientation in three directions. Current action inferred to have come from the west. Specimens were collected from 600 ft. above the base of the Buchan Caves Limestone at S.R. 52.

three directional nodes in material so apparently unsatisfactory for alignment suggests that current activity at that particular time was quite strong.

Bored shells are extremely rare and very few cases of encrusting forms have been noted. Specimens of *Spirorbis* have been found encrusting *Spinella* and algae and stromatoporoids have been observed completely coating brachiopods (more often *Buchanathyris* than *Spinella*). Penetrative algae are very common in some thin sections containing shells and in places can be seen to have been responsible for almost completely consuming a shell now remaining as a ghost completely laced by algal threads.

E. Systematic Description of Brachiopods

The brachiopod fauna of the Buchan Caves Limestone is of particular interest in that it is the typical brachiopod fauna of several other occurrences of Middle Devonian rocks associated with the Snowy River Volcanics in eastern Victoria. In the Buchan Caves Limestone brachiopods are more common than any other group, but are restricted to two common forms, the rest of the described fauna being rather rare and mainly restricted to muddy phases. The following forms are described:

Spinella buchanensis buchanensis n.gen., n.sp., n.subsp.
Spinella buchanensis scissura n.subsp.
Spinella buchanensis philipi n.subsp.
Spinella maga n.sp.
Buchanathyris westoni n.gen., n.sp.
Buchanathyris waratahensis n.sp.
Howittia howitti (Chapman) n.gen.
Uncinulus sp.indet.
Chonetes australis McCoy
Chonetes teicherti Gill
Chonetes buchanensis Gill
Chonetes spooneri n.sp.

The most common form is *Spinella buchanensis buchanensis,* which ranges through the entire sequence and almost disappears low down in the Pyramids Mudstone, the succeeding formation. The only change it exhibits through almost 800 feet of strata is for an increase in the proportion of forms with more rounded and flattened plications over forms with more angular plications. This trend towards flattening of plications resulted in a form with the first two plications tending to develop a median furrow. This is the subspecies *scissura*. The subspecies *philipi* is restricted to the muddier phases, while *Spinella maga* with its numerous fine plications has only been found in the upper part of the Buchan Caves Limestone.

The two species of *Buchanathyris* are likewise widely distributed through the sequence, but *B. westoni* is always much more common than *B. waratahensis* which tends to be limited to the muddy phases. All four chonetids are virtually limited to occurrences of mudstone or muddy limestone and apparently did not show very significant changes during the deposition of the sequence.

In the northern part of the area the last few feet of the formation are characterized by the incoming of *Howittia howitti* making a significant zone of overlap with the range of *Spinella buchanensis. Howittia howitti* extends well up into the overlying formations beyond the range of *Spinella buchanensis.* Associated with *Howittia hoyitti* and *Uncinulus* sp.indet. are fairly cimmon *Chonetes australis* (rarer lower down). This zone together with the zone of *Spinella buchanensis scissura* are the only fine subdivisions that can be made other than from considerations of lithology, ribbing in *Spinella,* and the succession of major groups migrating into the area.

Superfamily RHYNCHONELLACEA
Family CAMAROTOECHIIDAE Schubert and Le Vene, 1929
Genus **Uncinulus** Bayle, 1878
Uncinulus sp.ind.

Description. Shell small, wider and thicker than long, subpentagonal in outline. Maximum width located anterior of midlength. Surface costate, with about four costae occupying the sinus and about three or four costae on the flanks. Interior unknown. Measurements of M.U.G.D. 2227 from R.S.M. 77 are: length 5·7 mm., width 7·0 mm., thickness 6·5 mm.

Discussion. Rhynchonellid brachiopods appear to be absent from the Buchan Caves Limestone except for R.S.M. 77 where occasional *Uncinulus* have been found associated with *Chonetes*, *Howittia* and *Loxonema*.

Superfamily SPIRIFERACEA·
Family SPIRIFERIDAE King, 1846
Genus **Spinella** n.gen.
Type Species **Spinella buchanensis** n.gen., n.sp.

External morphology. Biconvex spiriferoid-shaped shells bearing a strong fold and sinus extending from the beak to the anterior margin. Plications strong, simple, and numerous. Palintrope high, and divided by a large delthyrium open to the apex. Ornamentation of concentric growth lines with superimposed tear or club-shaped spine bases not arranged radially or lying on radial costae.

Internal structure. Pedicle valve with two small teeth supported by strong dental lamellae extending for a considerable portion of the length of the valve, and having no subdelthyrial plate in the delthyrial cavity. Cardinal process located in the V formed by the crural plates uniting in the beak of the brachial valve. Cardinal process small, bilobed anteriorly, each lobe being surmounted by a comb of longitudinally aligned thin lamellae. Median septum absent from both valves, or with only a faint trace of a median septum in the pedicle valve. Spires consisting of about twelve turns in mature specimens, and not joined by jugal processes.

Discussion. Spinocyrtia Fredericks, 1916, based on *Spirifer granulosus* Conrad as type species, shows some similarity to the new genus. External morphology and the characteristic surface ornament of minute tear-shaped gránules tend to link the two genera, but *Spinella* does not have its granules aligned on radial costae and, more important, lacks the transverse delthyrial plate so characteristic of *Spinocyrtia*. No specimen ground down at the beak showed any trace of such a plate, nor, judging by the form of the adventitious calcium carbonate in the delthyrial cavity, was such a plate present. As the presence or absence of such a plate is of taxonomic importance the Buchan material must necessarily be referred to a different but possibly related genus. The European *Spinocyrtia ostiolata* to which the Buchan material was originally assigned by McCoy has a distinct surface ornament described by Maillieux (1909, p. 340) as "fines 'papilles" longitudinales ornant les lamelles d'accroissement et apparaissant, quad elles son bien dégagés comme de véritables stries rayonnantes."

Maoispirifer Allan, 1947 has a low median septum in the pedicle valve and differs externally, particularly in having an ornament of radial threads. Likewise *Acrospirifer* (*Spirifer primaevus* group), and *Paraspirifer* (*Spirifer cultrijugatus*

group) can be readily separated on external morphology. *Acrospirifer* has strongly developed radial ornament and alate form, and *Paraspirifer* has a very strongly carinate fold, correspondingly deep sinus, and surface ornament of undulating lines of tiny spines. *Hysterolites* has shorter dental lamellae in the pedicle valve, a feeble septum in the brachial valve extending approximately half the length of the valve, and surface ornament of "fines lamelles d'accroissement concentriques imbriquées, plus ou moins rapprochées" (Maillieux, 1931, p. 41). *Brachyspirifer* has strong dental lamellae in the pedicle valve, but has a short median septum in the brachial valve and surface ornament, described by Maillieux (1936, p. 98) as "nombreuses stries concentriques lamelleuses, portant au bord extérieur de nombreuses et fines cannelures serrées."

Acutatheca Stainbrook, 1945 differs from *Spinella* in being of subpyramidal shape, having dental lamellae which extend "nearly to hinge-line beneath cardinal shelf, but only a short way anteriorly along floor of valve", and having surface ornament of faint discontinuous radial ridges. *Eosyringothyris* Stainbrook, 1943 has a papillose surface with papillae not arranged in any pattern. However, presence of a transverse delthyrial plate allows ready separation from *Spinella*.

Eospiriferina Grabau, 1931 has a similar surface ornament to *Spinella* but externally is more comparable with *Elytha* Fredericks, 1918. *Elytha* differs from *Spinella* in outline, type of plications, presence of a median septum in the pedicle valve and having surface ornament of characteristic double spines.

Spinella buchanensis n.sp.

(Pl. 1, figs. 1-5; Pl. 11, figs. 4-10; Figs. 5-7; Table 2)

1867 *Spirifera laevicostata* (Valenciennes) McCoy, Ann. Mag. Nat. Hist., series (3), Vol. 20, p. 198. (Also published as Intercolonial Exhibition Essays No. 7, Melbourne, 1867, p. 21.)

1876 *Spirifera laevicosta* (Val.) McCoy, Prodromus of the Palaeontology of Victoria, decade IV, pp. 16-17, Pl. XXXV, figs. 2-2b.

1905 *Spirifer yassensis* de Koninck, F. Chapman, Proc. Roy. Soc. Vic., Vol. 18 (N.S.), Pt. 1, pp. 16-18, Pl. V, figs. 2 and 3.

1914 *Spirifer yassensis* de Koninck, F. Chapman, Australasian Fossils, Melbourne, Fig. 86 E, p. 161.

External morphology. Medium to large, subequally biconvex, somewhat wider than long spiriferoid-shaped shell with non-plicated sinus, and lateral slopes bearing 11 to 14 strong rounded simple plications separated by more angular grooves, with size of plications decreasing towards the cardinal extremities. Hinge line nearly equal to the greatest width of the shell. Gerontic specimens occasionally have the cardinal extremities constricto-produced, resulting in the hinge line corresponding with the line of maximum width.

Pedicle valve strongly convex with greatest curvature in the umbonal region, and arched regularly from the beak to the anterior and lateral margins. Sinus broad, extending from the beak to the anterior margin. Floor of sinus generally well rounded and non-plicate, but in rare cases bearing a faint trace of a median depression. Beak moderately strong, pointed, and slightly incurved. Palintrope high, striated transversely and longitudinally, and slightly to moderately arched. A groove runs along the palintrope near and parallel to the delthyrial margin. Delthyrium large, higher than wide and open to the apex.

Brachial valve moderately arched from the beak to the anterior commissure and moderately arched transversely. Fold strongly developed, fairly highly convex and clearly limited by angular furrows at the sides. No specimen shows any trace of a median depression in the fold. Beak small and incurved. Palintrope very low and divided by a broad, low notothyrium.

Ornamentation of concentric lamellae, feebly marked and irregularly spaced until near the anterior margin, there becoming strongly accentuated, particularly in gerontic specimens. With the exception of the palintrope, the entire surface is covered by closely-spaced tear-shaped spine-bases up to 0·3 mm. long (average 0·2 mm.) and of width equal to one-third or one-quarter of their length. Better preserved material shows these spine bases to have supported spines almost equal in height to the length of the spine base. There is no pronounced arrangement of the spines in radial lines or on radial costae as in the several species referred to *Spinocyrtia* by Stainbrook (1943). The surface ornament affects only the surface and a very limited depth of the shell, so that specimens broken out of hard limestone virtually never show evidence of having had a spinose surface. Best material is always obtained by weathering out from impure limestones.

Internal structure. Pedicle valve, with two small teeth supported by two strong dental lamellae descending from the sides of the delthyrial opening to the floor of the valve, the dental lamellae extending for up to three-quarters the length of the pedicle valve, progressively changing their shape and thickness away from the beak as illustrated by Fig. 5. A faint trace of a median septum may occur in some specimens, but most lack this. No specimen sectioned shows any trace of a transverse delthyrial plate as seen in *Spinocyrtia*. Deposition of calcium carbonate has occurred at the posterior end of the pedicle valve with the result that the shell walls and dental lamellae appear to be abnormally thickened. Muscular markings indistinct.

Brachial valve with two elongated well-defined dental sockets which may be up to twice the width of the teeth inserted in them from the pedicle valve. Crura supported by crural plates inclined towards the median plane, converging towards the beak, and uniting there. The space between the crural plates just anterior of where they unite serves as foundation for the cardinal process. Cardinal process small, consisting of a somewhat irregular plate filling the space between the converging crura, and becoming strongly bilobed anteriorly, each lobe being surmounted by a comb of longitudinally aligned thin lamellae (see Fig. 5). Spires in a shell 42 mm. wide are composed of 12 turns. Primary lamellae are completely devoid of jugal processes. No trace of median septum occurs in any specimen of a brachial valve examined. The posterior portion of the valve may be slightly thickened by adventitious calcium carbonate. Muscular impressions indistinct.

Measurements. An abundance of well-preserved material suitable for measurement was obtained weathered out from impure limestone outcropping in the road cutting on the first U-bend south of Murrindal State School. This is just above the base of the Pyramids Mudstone and represents virtually the last of the genus *Spinella* to occur in the Buchan Group. Measurements made are appended as Table 2 and plotted as Fig. 6.

Measurements of the holotype (M.U.G.D. 2152) are: length of pedicle valve 23·4 mm., maximum width 34·8 mm., thickness 22 mm.

Types. Holotype M.U.G.D. 2152. Paratypes are partly sectioned specimens M.U.G.D. 2298, 2299, 2300 and 2301. Measured specimens are M.U.G.D. 2293-2299 and 2302-2309. All these specimens came from a road cutting on the Buchan-

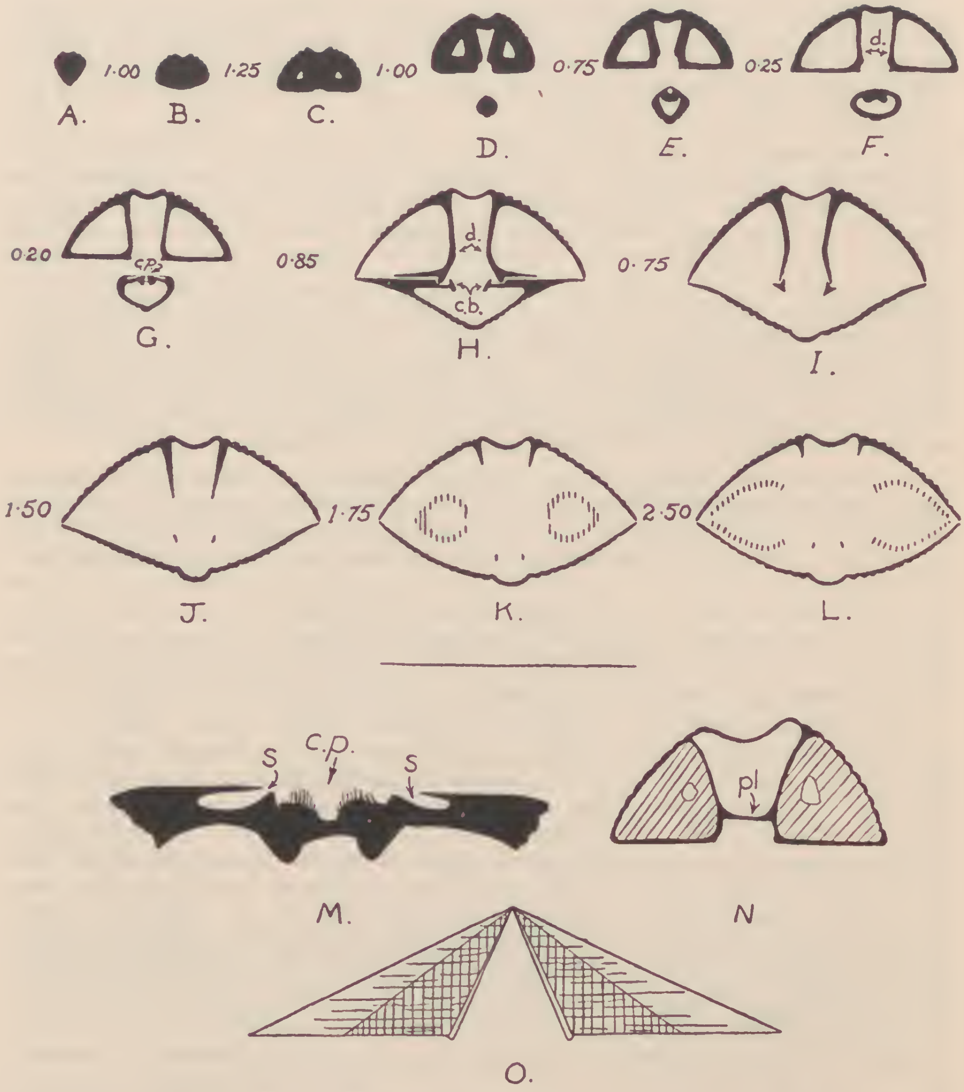


FIG. 5.—A.-L.—Series of 12 successive sections, × 1, through the beak of *Spinella buchanensis*. Distances shown are in mm. between each section. M.—Enlargement of cardinal process shown in Fig. G. N.—Section through the beak of *Spinocyrtia granulosa* from the Moscow Formation. Cayuga Lake, New York, showing subdelthyrial plate. O.—Diagrammatic representation of pedicle palintrope of *Spinella* showing the division into differently ornamented zones. (c.b. crural bases, c.p. cardinal process, d. dental lamellae, pl. subdelthyrial plate, s. sockets.)

Gelantipy Road just south of Murrindal State School. Figured specimens M.U.G.D. 2157 and M.U.G.D. 2158 illustrate the angular ribbed and flatter ribbed types from lower down the sequence.

Discussion. Spinella buchanensis has been previously referred to *Spirifer laevicosta* (Valenciennes) and *Spirifer yassensis* de Koninck. Chapman (1905) stressed the general dissimilarity between the Buchan material and *Spirifer laevicosta* from the Eifel, and referred it to *Spirifer yassensis* on gross morphological grounds.

Since then it has been referred to as *Spirifer yassensis* and this determination has been used to strengthen the correlation of the Buchan sequence with the Middle Devonian of New South Wales.

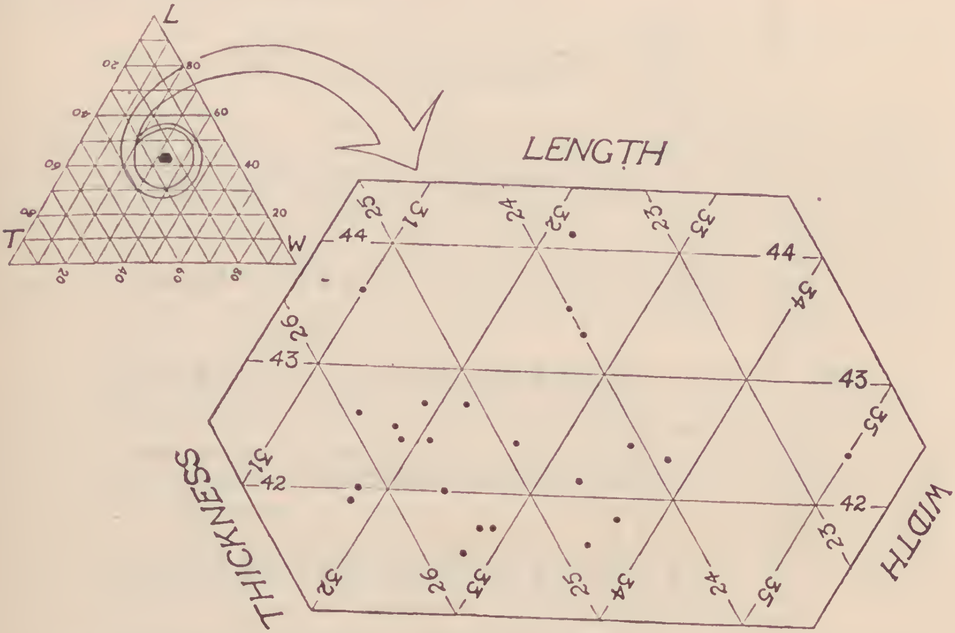


FIG. 6.—100% three-factor diagram of length, width, and thickness of the 23 specimens of *Spinella buchanensis* listed in Table 1.

As the type specimen of *Spirifer yassensis* has been irredeemably lost, no accurate comparison with the original specimen can be made, and until such time as a neotype is designated no fine comparisons can be drawn. Specimens of *Spirifer yassensis* available to the author show rather a wide variation, indicating that more than one form is represented. Specimens from the "Wallpaper Locality" show a marked recapitulation in surface ornament with an overall decay of radial striations into the greatly elongated granules described by Allan (1947). Later stages show progressive shortening and increased density of granules so that it is feasible that further development in this direction could result in still shorter and more randomly distributed granules with the ultimate development of the surface ornament of *Spinella buchanensis*. Specimens of *Spinella buchanensis* are generally larger and proportionately thinner than the specimens of *Spirifer yassensis* available to the

TABLE 2

Measurements of Spinella buchanensis

L = length; W = maximum width; T = thickness at right angles to commissure.

	L(ped.) (in mm.)	L(br.) (mm.)	W (mm.)	T (mm.)	% of L (ped.)	% of W	% of T	L(ped.) / W	T/W	Number of Plications	Remarks
1	27·5	23·0	34·1	19·8	41·8	33·7	24·5	·81	·58	13	M.U.2293
2	26·7	22·0	35·3	21·2	42·4	32·1	25·5	·76	·60	13	Sectioned
3	30·7	24·5	38·0	22·6	41·6	33·6	24·8	·81	·60	12	Sectioned
4	21·6	17·6	28·5	15·8	42·4	33·5	24·1	·76	·56	12	M.U.2294
5	22·4	18·1	30·0	17·8	42·7	31·9	25·4	·75	·59	12	M.U.2295
6	27·5	21·4	34·9	19·9	42·4	35·0	22·6	·79	·57	14	Sectioned
7	24·6	20·5	31·9	18·8	42·4	32·7	24·9	·77	·59	13	Sectioned
8	22·9	18·5	29·4	17·5	42·0	31·8	26·2	·78	·59	13	Sectioned
9	33·8	26·7	42·7	25·9	41·7	32·9	25·4	·79	·60	13	Sectioned
10	15·4	12·7	20·4	11·3	43·3	32·7	24·0	·76	·55	11	M.U.2296
11	20·7	17·5	27·5	16·6	42·4	31·9	25·7	·75	·60	13	M.U.2297
12	27·0	22·4	35·0	21·4	42·0	32·4	25·6	·77	·61	12	Partly sectioned Paratype M.U.2298
13	27·6	23·0	38·8	22·6	43·6	31·0	25·4	·71	·58	12	M.U.2302
14	22·2	18·5	28·0	16·4	42·1	33·3	24·6	·80	·59	11	M.U.2303
15	24·5	20·4	33·0	19·5	41·9	31·8	26·3	·74	·59	13	Partly sectioned. Paratype M.U.2299
16	26·7	21·9	35·4	20·9	42·7	32·2	25·1	·75	·59	13	M.U.2304
17	24·3	19·9	32·4	17·8	43·5	32·5	24·0	·75	·55	15	M.U.2305
18	17·0	14·7	23·0	14·1	42·6	31·5	25·9	·74	·61	11	Sectioned
19	16·6	14·5	22·2	13·4	42·5	31·8	25·7	·75	·60	12	M.U.2306
20	24·5	20·3	33·6	18·0	44·1	32·2	23·7	·73	·54	12	Sectioned
21	22·9	19·0	29·0	18·0	41·5	32·8	25·7	·79	·62	13	M.U.2307
22	26·8	21·6	34·0	20·8	41·7	32·8	25·5	·79	·60	12	M.U.2308
23	13·6	10·8	17·0	9·6	42·3	33·8	23·9	·80	·56	12	M.U.2309

author. It could well be that the specific differences outlined are due to existence in different environments or are the expression of geographic isolation, but available material shows *Spinella buchanensis* to be probably more highly advanced than "*Spirifer yassensis*".

Best preserved material has come from the top of the Buchan Caves Limestone and the base of the Pyramids Mudstone. Material lower in the sequence shows some difference from the type material. Through the sequence there is a general increase in size and decrease in angularity of plications.

Distribution. Spinella buchanensis ranges through the entire Buchan Caves Limestone into the lower horizons of the Taravale Mudstone (Pyramids Mudstone in the north), where it apparently becomes extinct.

Spinella buchanensis scissura n.subsp.
(Pl. I, figs. 6 and 7)

External morphology. Large, subequally biconvex, spiriferoid-shaped shells, somewhat wider than long with non-plicated, strong, rounded fold and sinus and plicated lateral slopes bearing about 10 or 11 flat-rounded simple plications separated by more angular grooves. Plications immediately flanking the fold and sinus have a median groove running down the axis of the plication. Successive plications away from the fold or sinus show less tendency to medial grooving so that the third plication on the pedicle valve or the second plication on the brachial valve and successive plications are comparatively flattened but without the medial groove. Cardinal extremities somewhat rounded.

Pedicle valve convex, with maximum curvature in the umbonal region and arched regularly from the beak to the anterior and lateral margins. Sinus broad, rounded, extending from the beak to the anterior margin and without a median depression. Beak strong and moderately strongly incurved. *Brachial valve* convex and moderately arched from the beak to the anterior margin and moderately arched transversely. Fold strongly developed, sharply delineated and bearing a median depression; generally rounded in younger stages and sub-quadrangular in adult specimens. *Ornamentation* consisting of coarse concentric growth lines mainly formed by alignment of the thicker ends of tear-shaped spine bases into concentric lines corresponding to positions previously occupied by the commissure.

Internal structure. Very little is known of the interior of *Spinella buchanensis scissura* because the bulk of available material consists of disarticulated valves. However, evidence from fragmentary material shows strong dental plates in the pedicle valve and some adventitious material in the pedicle beak. Muscular markings unknown.

Measurements. The holotype is somewhat mashed but has the following measurements: length of pedicle valve 28·6 mm., width 39 mm., thickness 17·8 mm., maximum width of fold 13·2 mm.

Type. Holotype M.U.G.D. 2153.

Discussion. Spinella buchanensis scissura is of considerable stratigraphic value at Buchan. Bilobed plication occurs only in forms from a restricted zone in the upper part of the Buchan Caves Limestone, although predecessors at lower horizons have the flattened plications which in subsequent stages become bilobed. This zone has been recognized in the Jackson's Crossing Limestone at J.C. 46.

Spinella buchanensis philipi n.subsp.

(Pl. II, figs. 1-3, 11, 12)

External morphology. Large, almost equally biconvex, obese, spiriferoid-shaped shells with non-plicated, strong, rounded sinus and plicated lateral slopes bearing 13 to 18 well-rounded simple plications separated by more angular grooves. Maximum width occurs at the hinge line.

Pedicle valve strongly convex with maximum curvature in the umbonal region. The non-plicate sinus starts at the beak and extends to the anterior margin. Beak moderately strong, pointed and strongly incurved. Palintrope high and striated transversely and vertically, the vertical striations being deeply incised. Palintrope strongly incurved over a delthyrium which is higher than wide, but smaller than in *S. buchanensis*. *Brachial valve* moderately arched longitudinally and transversely. Fold strongly developed and fairly highly convex. Beak small and incurved over a low palintrope.

Ornamentation of concentric lamellae becoming coarse near the anterior margin. With the exception of the palintrope the whole surface is covered by closely-spaced tear-shaped or ovate spine bases averaging 0·2 mm. long. Individual spine bases are directed radially but may be oblique on the sides of plications, where they may tend to mount the plication anteriorly. Spine bases are not arranged in radiating lines but generally have their thicker ends aligned in concentric lines corresponding to positions occupied by the commissure during growth. This results in what appears to the naked eye as irregular rugose growth lines. However, this concentric arrangement need not occur over the entire surface but may be lost on the flanks.

Measurements (mm.).

	Holotype M.U.G.D. 2156	Paratype M.U.G.D. 2220	Paratype M.U.G.D. 2221
Max. width	32·7	35·3	35·3
Length	22·8	25·6	27·1
Thickness	Approx. 24·4	Approx. 26·8	26·8

Discussion and distribution. Spinella buchanensis philipi differs from *S. buchanensis* in the arrangement of spine bases along growth lamellae, the greater obesity, and the more strongly incurved beak of the pedicle valve.

Specimens were obtained weathered out of calcareous mudstone of the Cameron Mudstone Member of the Buchan Caves Limestone and from the Spooner Creek muddy phase of the Basin Limestone. These occurrences are stratigraphically much lower than the type locality for *Spinella buchanensis buchanensis* at Murrindal and correspond to about the middle of the Buchan Caves Limestone.

Spinella maga n.sp.

(Pl. I, fig. 8)

External morphology. Moderately large, subequally biconvex, spiriferoid-shaped shell with non-plicated, strong, rounded sinus and fold and with plicated lateral slopes bearing 18 or 20 simple rounded plications separated by narrower grooves. Plications considerably smaller and inserted much earlier than in *S. buchanensis*. Hinge line considerably less than the greatest width of the shell.

Pedicle valve strongly convex, with greatest curvature in the umbonal region, and arched regularly from the beak to the anterior and lateral margins. Sinus well-rounded, and commencing at the beak. Beak very strongly incurved, almost concealing the palintrope. *Brachial valve* moderately arched from the beak to the anterior and lateral margins. Fold well-defined and devoid of any trace of a median depression. Beak strongly incurved, concealing the low palintrope. *Ornamentation* appears to have consisted of occasional concentric lamellae, the entire surface being covered by fine granules.

Measurements. The holotype (M.U.G.D. 2154) has the following dimensions: length 23·6 mm., maximum width 28·5 mm., thickness 19·5 mm.

Discussion. Spinella maga is readily distinguished from *Spinella buchanensis* by the greater number of lateral plications, the strongly incurved pedicle beak, and the granular surface ornament. This species is rare and has only been found in the uppermost part of the Buchan Caves Limestone.

Ontogeny of Spinella

Solution of silicified limestone from the slope west of Fairy Creek, opposite the Fairy Cave, about 50 ft. above the creek, yielded a mass of fragments of partly silicified shells, including a few almost complete specimens of younger growth stages. The material available, when coupled with later growth stages seen in ephebic shells, was sufficient to infer the complete ontogeny.

Description of Specimens (see table of measurements)

The smallest individual in the collection (M.U.G.D. 2045) represents the species in the nepionic stage. The shell is about 1·1 mm. long and 0·65 mm. thick, but the cardinal extremities are not preserved, although the shell outline appears to have been sub-circular. The pedicle valve has a fairly high palintrope which appears to have been almost completely occupied by a large pedicle opening which extended into the brachial valve. Both valves are convex, with the pedicle valve slightly more convex than the brachial valve. Only the slightest trace of a sinus appears in the pedicle valve.

The smallest well-preserved specimen (M.U.G.D. 2046) measures 1·5 mm. long, 1·7 mm. wide and 0·9 mm. thick. Hinge line is short and cardinal extremities are well rounded. Outline sub-circular, with a faint sinus appearing in the pedicle valve. Pedicle opening now almost confined to the pedicle valve. Surface with poorly preserved spine bases demonstrating early development of discrete spines. Successive stages show an increase in height of the pedicle palintrope resulting in cyrtinoid-shaped individuals. This feature is illustrated by M.U.G.D. 2047, which has approximately the same length and breadth as the preceding specimen but has a higher pedicle palintrope. Pedicle sinus now more distinct and extending 0·5 mm. from the pedicle beak. A corresponding weak plication occurs in the anterior commissure and is bounded on each side by a faint plication corresponding to the first pedicle-valve plication now commencing insertion. Surface spinose.

Specimen 4 (M.U.G.D. 2048) is slightly larger than the preceding but represents almost the same growth stage. However, it represents the greatest degree of cyrtinoid shape assumed during ontogeny and in addition is the smallest specimen to show fine growth lines along the anterior margin. Specimen 5 (M.U.G.D. 2049) represents the same growth stage as specimen 4.

TABLE 3

Measurements of specimens illustrating the ontogeny of Spinella buchanensis

Specimen No.	M.U. G.D. regd. No.	L(ped) in mm.	L(br) in mm.	W in mm.	T (ped+br) in mm.	L(ped)/W	T(ped+br)/L(ped)
1	2045	1·1 appr.	—	—	0·65	—	·60
2	2046	1·5	—	1·7	0·9	·88	·60
3	2047	1·5	—	1·7	1·1	·88	·73
4	2048	1·6	—	1·85	1·2	·86	·75
5	2049	1·65	—	2·1	1·2	·78	·73
6	2050	2·3	1·9	2·6	1·6	·88	·70
7	2051	2·3	—	2·7	1·65	·85	·70
8	2052	—	—	3·2 appr.	—	—	—
9	2053	3·2	2·8	3·8	2·0	·84	·63
10	2054	3·8	3·2	4·6	2·7	·83	·52
11	2055	—	4·6	7·2	—	—	—
12	2056	—	5·4	—	—	—	—

Specimens 6 and 7 (M.U.G.D. 2050 and 2051) have a low rounded plication on each side of the median sinus in the pedicle valve. The brachial valve has well-defined furrows delineating the median fold, and in addition the first plication on either side of the delineating furrow has started to appear. Tiny radially-directed spine bases are seen in a few patches. Some of them have their anterior ends aligned in a direction which would correspond to the anterior commissure at that stage of growth. Specimen 7, being slightly larger than specimen 6, has a better defined pedicle sinus and stronger neighbouring plications.

Specimen 8 (M.U.G.D. 2052) consists of two fragments of an accidentally crushed shell originally about 3·2 mm. wide. A large fragment of the pedicle valve shows the beak and dental plates intact. The dental plates are strong, moderately divergent and 1·0 mm. in length. A very low median septum extends from the beak to beyond the mid point of the pedicle valve.

Specimen 9 (M.U.G.D. 2053), which is 3·8 mm. wide, has two strong rounded plications and two feeble plications on either side of the median fold. The hinge line is proportionately longer (2·6 mm.) than in younger specimens but the cardinal extremities are still very well rounded. The pedicle valve is still more convex than the brachial valve and the palintrope is becoming more strongly delineated. The external appearance is reminiscent of some species referred to the genus *Elytha*.

Specimen 10 (M.U.G.D. 2054) is unfortunately obscured by a considerable amount of adhering silica. It is 4·6 mm. wide and represents the stage where insertion of the fifth plication has just commenced. Cardinal extremities are still well rounded and the outline is almost the same as specimen 9.

Specimens 11 and 12 (M.U.G.D. 2055 and 2056) are incomplete brachial valves but show spine bases covering the surface. Specimen 11 shows these spine bases to be club-shaped, with the thick end pointing anteriorly.

Spine bases preserved in the centre of the shell measure 0·2 mm. long and 0·05 mm. wide at the widest point. The spines are not radially aligned and show no evidence of development from radial striae. However, the clubbed ends of the spine bases tend to be aligned parallel to the anterior commissure, but need not necessarily be so. Specimen 11 shows six well-defined plications.

Specimen 13 is an incomplete pedicle valve showing dental lamellae which are much stronger and extend much further (more than half way) along the floor of the pedicle valve than in specimen 8. There is no longer any trace of a median septum on the floor of the pedicle valve.

Inferred Ontogeny

Outline. Throughout life the width is greater than the length, the ratio of length to width being ·88 in specimens 1 or 2 mm. long and falling off slightly in larger specimens. Very young specimens are sub-circular and even in comparatively advanced growth stages the cardinal extremities are still well rounded but become more acute in ephebic stages. With increased age the cardinal extremities become blunter again and may become constricto-produced in gerontic individuals. In most stages the width at the hinge is less than the greatest width below.

Valve convexity. Specimens about 1 mm. long or less have both valves nearly equally convex, but the pedicle valve rapidly becomes more convex than the brachial and remains so throughout life. A study of Fig. 3 illustrates the change in convexity better than a lengthy description. The height of the palintrope is variable (see specimens 2 and 3) but increases rapidly in young stages to give a pronounced

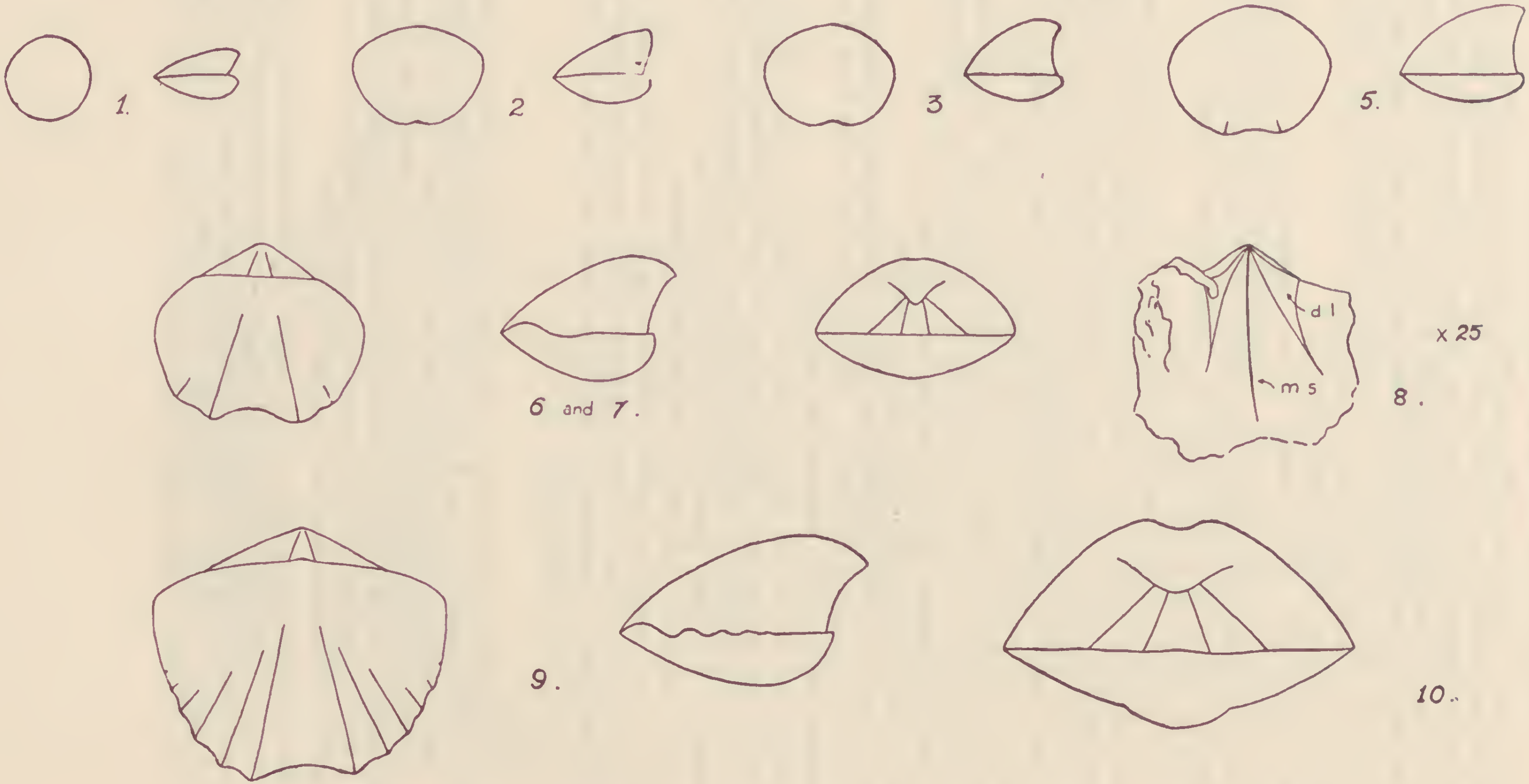


FIG. 7.—Line drawings of vertical, lateral, and posterior aspects of specimens illustrating the ontogeny of *Spinella buchanensis*. Numbers are those used in the text and Table 2. All illustrations are enlarged by 10 except 8, which shows the dental lamellae (d.l.) and the fine median septum (m.s.) developed at an early stage.

cyrtinoid aspect (e.g., specimens 3 and 5) in individuals about 1·5 mm. long. The height is then three-quarters the length. However, this ratio falls off and the cyrtinoid appearance is rapidly lost, although mature specimens continue to have an elevated palintrope.

Plications. Shells less than 0·5 mm. long are completely smooth. At this stage an incipient median sinus on the pedicle valve starts to appear. Very soon after this a corresponding incipient fold appears on the brachial valve. However, fold and sinus are not readily noticeable until the shells reach 1 mm. long. The bounding plication on each side of the median sinus appears when the shell is about 1·5 mm. long. The second plication starts to appear when the pedicle valve is about 2·2 mm. long. On a pedicle valve 3·2 mm. long there are four plications; 3·8 mm. long, five plications; 5·5 mm. long, six plications; 12 mm. long, nine plications; 25 mm. long, eleven to fifteen plications.

Pedicle opening. In very small stages 1 mm. or less in length the pedicle opening is shared by both valves, but becomes restricted to the pedicle valve in early neanic stages. The triangular delthyrium is bounded by dental lamellae which extend further along the floor of the pedicle valve as the age increases. A low median septum is found in a specimen 3·2 mm. wide but does not occur in larger specimens. This would indicate that either the very low median septum need not occur or that it becomes atrophied in later life.

Microscopic ornament. Very small shells were probably completely smooth, but there is an early development of characteristically club-shaped surface spine bases. The spines are not derived from radii and bear no resemblance to the surface ornament of *"Spirifer" yassensis* de Koninck.

Phylogeny of Spinella buchanensis—Inferred from Ontogeny

If it is assumed that evolutionary history is to some degree recapitulated during the ontogeny of brachiopods, several possible suggestions as to phylogeny of *Spinella buchanensis* can be inferred.

The early development and subsequent modification of a cyrtinoid shape suggests development from a group externally comparable to the genus *Cyrtia*. An early development of surface spines suggests a line of spinose ancestors, the earlier members of which were more cyrtinoid in shape than later representatives. With increase of number of plications and loss of cyrtinoid appearance the developing individual assumes a form very strongly reminiscent of *Eospiriferina* Grabau. *Eospiriferina* has five or six rounded plications, rounded cardinal extremities, strong divergent dental lamellae extending for about a quarter the shell length, a faint median septum and very similar surface ornament to *Spinella buchanensis*. Specimen 11 corresponds to the *Eospiriferina* stage having spine bases with the same proportional length to the length of the pedicle valve as those illustrated by Grabau (1933, Pl. L, figs. 8-10) and in addition showing six plications and the same gross characters. *Eospiriferina* comes from the lower Middle Devonian of China according to Grabau and so could be related to *Spinella buchanensis*.

At no stage during ontogeny is there any evidence of forms having radiate surface ornament reminiscent of the ornament of *"Spirifer" yassensis* mentioned by Allen (1947, p. 447). Surface granules are never greatly elongated or aligned in radiating lines, but nevertheless *Spinella buchanensis* is quite feasibly a direct descendant of *"Spirifer" yassensis* derived by decay of radial ornament.

Genus **Howittia** n.gen.

Type Species **Spirifer howitti** Chapman, 1905

External morphology. Subequally biconvex spiriferoid-shaped shell with uniplicate anterior commissure and plicated lateral slopes. Pedicle valve more convex than the brachial, with sinus originating at the beak and bearing one to three or four simple plications. Delthyrium open to the apex. Brachial valve gently convex with bilobed median fold. Palintrope low. Ornamentation of growth lamellae and fine papillated radial costellae.

Internal structure. Dental lamellae fairly strong. Short median septum in pedicle valve. Teeth and sockets strong. Cardinal process V-shaped with surface of longitudinally aligned lamellae. Jugum absent. Spires of about ten turns in mature specimens. Musculature unknown. Shell substance fibrous and impunctate.

Discussion. Howittia differs from *Spinella, Spinocyrtia, Plectospirifer, Delthyris, Elytha* and other genera with non-plicated sinus by bearing plications on the sinus. *Howittia* bears less plications on the sinus than *Costispirifer* and *Fimbrispirifer* and is nearest in external morphology to some forms referred to *Tylothyris* by Stainbrook (1943), such as *Tylothyris randalia,* but lacks the strong median septum of *Tylothyris*, only a low septum being developed in the beak of the pedicle valve. *Tylothyris* North, 1920 lacks plications on the fold and sinus and has a strong apical callosity, absent in *Howittia. Indospirifer* Grabau has generally more plications in the sinus and has a fanwise surface ornament which may be pustulose.

Howittia howitti (Chapman), 1905

(Pl. II, figs. 13-17; Fig. 8)

1905 *Spirifer howitti* Chapman, Proc. Roy. Soc. Vic., Vol. 18 (N.S.), Pt. 1, pp. 18-19, Pl. V, figs. 4-6.

External morphology. Shell moderately large, subequally biconvex spiriferoid-shaped, wider than long, with uniplicate anterior commissure. Lateral slopes bearing seven or eight strong, sharply rounded, simple, rarely bifurcating plications, the size of plications decreasing towards the cardinal extremities. Intervening furrows wider than the plications.

Pedicle valve strongly and regularly convex. Sinus originating at the beak, well delineated, strongly developed, extending anteriorly to form a lingual extension truncating the opposite fold. Sinus in an adult specimen bearing one to three plications lower than those on the lateral slopes, not formed by bifurcation, but inserted between the median plication and the plication on either side delineating the sinus. Plications in sinus commencing as faint swellings, expanding, and finally becoming well defined. Median plication characteristic, but the other two sometimes not developed even in large specimens. Slopes gently curved from sinus to cardinal extremities, but more strongly curved from back to front, slightly concave on each side of the beak. Umbo strongly developed, elevated, projecting beyond the hinge line. Beak strong, pointed, and slightly to moderately incurved. Palintrope fairly high, moderately arched, striated transversely and longitudinally. Delthyrium large, open to the apex.

Brachial valve gently curved along the midline from umbo to front, more strongly so over the beak, gently arched transversely. Fold originating at the beak, subquadrangular in cross section at first, but soon becoming bilobed, the median groove

corresponding to the median groove in the opposite valve. Lateral grooves corresponding to the plications of the sinus occurring on the flanks of the fold. Umbo low, gently convex. Beak small, short, strongly incurved. Palintrope low.

Ornamentation of widely spaced distinct growth lamellae, occasionally strongly accentuated, zigzagging up and down plications. With the exception of the palintrope, entire surface covered by numerous minute papillated radial costellae generally spaced about 0·1 mm. apart.

Internal structure. Pedicle valve with two strong teeth supported by fairly well developed dental lamellae descending from the sides of the delthyrial opening to the floor of the valve, but not extending along the floor beyond the level of the hinge line. Short median septum in the beak. Transverse delthyrial plate absent in any specimen sectioned. Musculature unknown.

Brachial valve with two strong dental sockets housing the teeth from the opposite valve. Crura supported by crural plates inclined towards the median plane of the

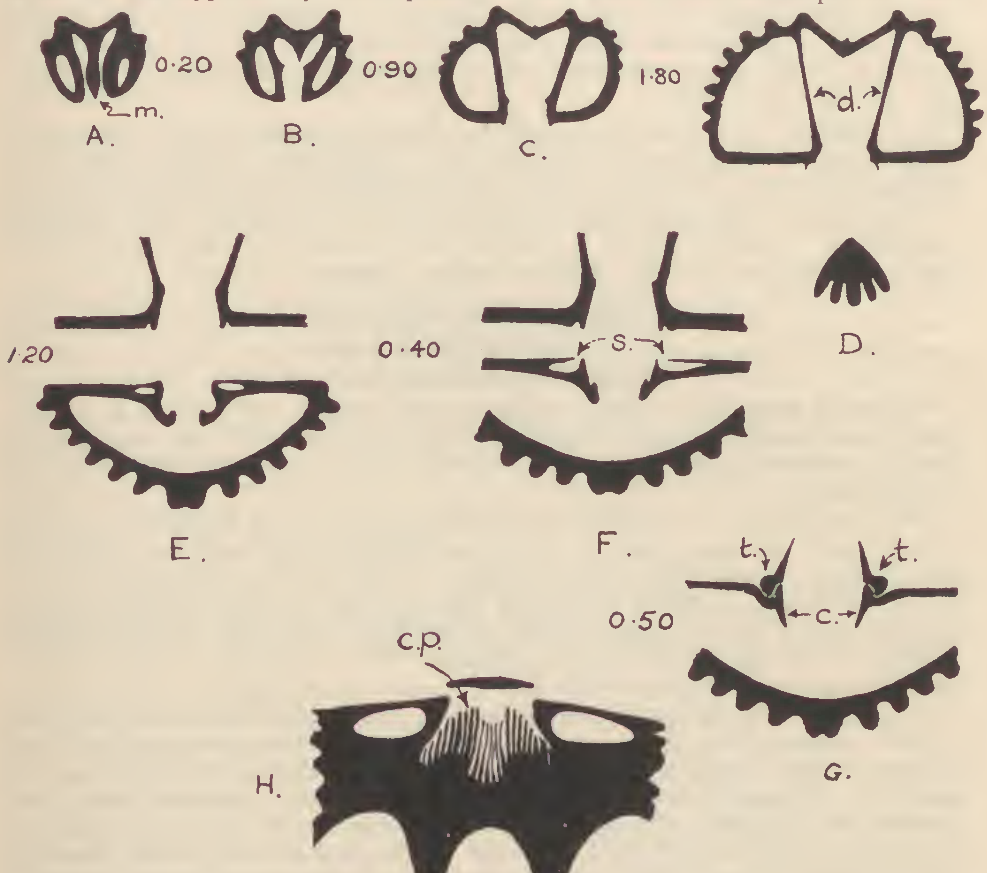


FIG. 8.—A.-G.—Series of seven successive sections, × 3, through the beak of *Howittia howitti*. Distances shown are in mm. between the sections. H.—Enlargement of the cardinal process, × 10. (c. crural bases, c.p. cardinal process, d. dental lamellae, m. median septum, s. dental sockets.)

brachial valve and uniting in the beak, the space between the crura just anterior of the point of union serving as location for the cardinal process. Cardinal process V-shaped, the entire surface, including the two short anteriorly directed arms, being surmounted by a comb of longitudinally aligned thin lamellae (see Fig. 8). Spires in a shell 24 mm. wide composed of about ten turns. Primary lamellae completely devoid of jugal processes. Muscular impressions unknown.

Measurements. Chapman (1905, p. 18) gave measurements of three specimens from Bindi; the only complete one is given here as No. 4. All three specimens were obtained from the base of the Pyramids Mudstone on bend immediately south of Murrindal State School.

	1	2	3	4
Width	29·5	22·5	20·2	28
Length ped. valve	22·2	approx. 16	11·3	21·5
Thickness	18·0	14·0	10·6	15·5

Types. Chapman's types are in the National Museum of Victoria. Hypotypes are M.U.G.D. 2159, 2160.

Distribution. Howittia howitti occurs at Bindi and Buchan and forms a well-marked zone without overlap with the zone of abundant *Spinella buchanensis*, although *Howittia howitti* occurs with the last stragglers of the *Spinella* stock.

Discussion. Chapman's original comparison of this species with "*Spirifer*" *mucronatus* is rather strained as *Mucrospirifer mucronatus* has a non-plicated fold and sinus and has totally different surface ornament.

Superfamily ROSTROSPIRACEA

Genus **Buchanathyris** n.gen.

Type Species **Buchanathyris westoni** n.sp.

External morphology. Shell subequally biconvex and sub-rounded in outline. Beak small, bearing a circular foramen. Surface ornament of concentric growth lines or projecting growth laminae. Pedicle valve occasionally with a shallow median sinus.

Internal structure. Hinge teeth supported by short stout dental lamellae and inserted into deep dental sockets. Dorsal beak with a short hinge plate, perforated by a foramen immediately inside the beak, and giving rise anteriorly to crural processes abruptly recurved and giving rise to a pair of laterally directed spiral cones of about twelve turns. Jugum consisting of two limbs rising ventrally, uniting, and being produced into a somewhat postero-ventrally directed process. Median septum absent from both valves.

Discussion. The essential difference between *Buchanathyris* and related athyroid genera is found in the nature of the jugal process. *Athyris*, *Cleiothyridina*, and *Composita* have a saddle-shaped median plate from which further processes are given off. *Buchanathyris* lacks such a plate and appears to be more closely comparable with *Protathyris* Kozlowski than with these median-plate-bearing genera. *Protathyris* and *Buchanathyris* have rather simple jugal process, but the jugum in *Protathyris* bifurcates above the point of union, giving rise to two accessory lamellae which recurve dorsally, parallel to the bases of the primary lamellae. The jugum of *Buchanathyris* does not bifurcate but ends as a postero-ventrally directed median apophysis.

Buchanathyris westoni n.sp.

External morphology. Small, almost equally biconvex, sub-rounded shell with maximum width almost at midlength. Length generally slightly greater than width, although occasionally less. Maximum thickness slightly posterior of midlength. Anterior commissure generally slightly sinuate but occasionally without a fold.

Pedicle valve slightly more convex than brachial valve, fairly strongly and regularly arched transversely and longitudinally with maximum curvature in the umbonal region. A wide, indistinctly defined, shallow sinus generally present, but not traceable far towards the umbo. Sinus quite frequently virtually absent. Umbonal region prominent. Beak strong, projecting beyond the hinge line, strongly incurved, and bearing a circular foramen.

Brachial valve moderately arched longitudinally and transversely, with maximum curvature in the umbonal region, an indistinct fold occasionally occurring near the anterior margin. Beak short, blunt, and concealed by the opposite beak. Ornamentation generally not seen in specimens broken out of hard limestone. Specimens weathered out with fine (rarely coarse) concentric growth lines, usually absent from the posterior parts of the shell.

Internal structure. Pedicle valve with two short strong teeth supported by dental lamellae descending and curving outwardly to the floor of the valve. Dental lamellae extending posteriorly into the beak and merging into the shell wall, but not extending anteriorly beyond the level of the teeth. Muscular impressions poorly defined.

Brachial valve with no clearly defined cardinal process. Hinge plate short, perforated by a large sub-rectangular foramen immediately inside the beak. Dental sockets deep. Crural processes thin, curved ventrally and slightly anteriorly, and acutely recurved, giving rise to thin lamellae. Lamellae initially directed posteriorly, curving ventrally and then running parallel to the floor of the pedicle valve in an anterior direction, then giving rise to a pair of laterally directed spiral cones consisting of about nine turns in a shell 15 mm. wide. Jugum consisting of two limbs attached posteriorly of midlength of that part of the initial turn of each spiral paralleling the floor of the brachial valve; limbs of jugum uniting at an acute angle, forming a structure V-shaped in horizontal cross-section, and prolonged postero-ventrally as a short median apophysis.

Measurements. Measurements of 75 specimens are plotted as Figs. 10 and 11. The material was collected weathered out on a ledge of a prominent river cliff on the south side of the Buchan River immediately above the East Buchan overthrust.

Discussion. Buchanathyris westoni is very similar externally to many Lower and Middle Devonian species referred to *Athyris*. In most cases no information is available on these species about internal structure and the assignment to *Athyris* has been made in most cases solely on the basis of external similarity. This is unfortunate in that the critical generic characters of athyroid brachiopods are mainly confined to the interior of the brachial valve. The nature of hinge plate, jugal processes and median septum in the brachial valve are of greater taxonomic importance than gross variation of external morphology.

Types. Holotype M.U.G.D. 2184; paratype M.U.G.D. 2312; measured specimens M.U.G.D. 2801-2875 inclusive.

FIG. 9.—*Buchanathyris westoni.* A.-K.—Series of eleven successive sections, × 5, at right angles to the plane of the commissure. L.-T.—Series of nine successive sections, × 3, parallel to the plane of the commissure from the brachial to the pedicle valve (dotted lines represent structure seen by transparency). U.—Horizontal section through the hinge plate showing the visceral foramen. V.—Reconstruction of jugal process. W.—Semi-diagrammatic representation of reconstructed brachidium, × 3. Distances shown are in mm. between successive sections. (c.r. crural processes, d. dental lamellae, f. visceral foramen, h.p. hinge plate, j. jugum, t. teeth.)

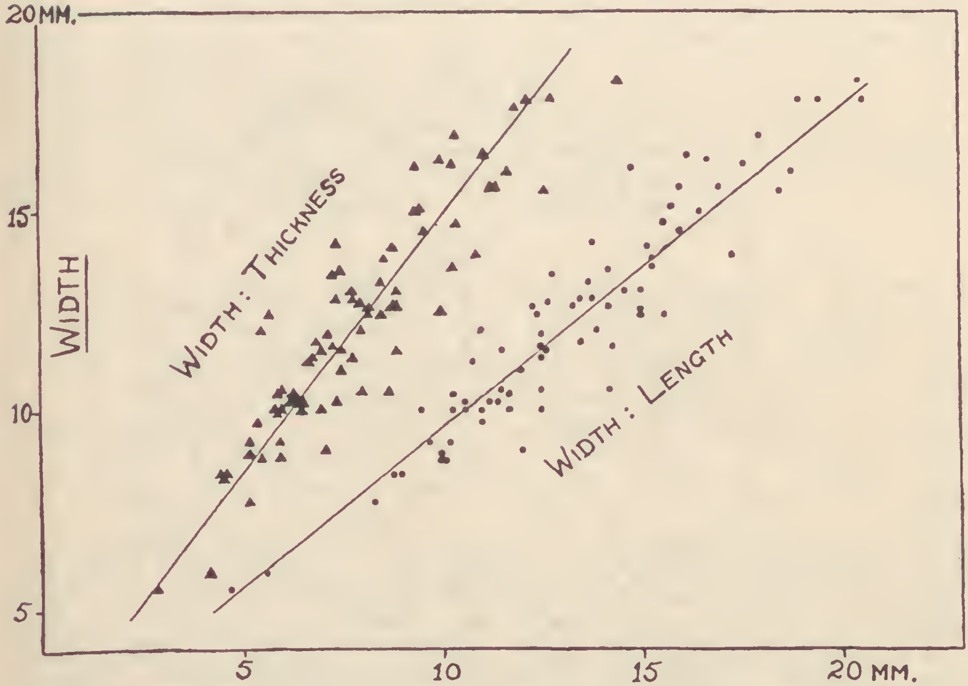


FIG. 10.—Measurements of 75 specimens of *Buchanathyris westoni* from the Buchan Caves Limestone in a river cliff on the S. side of the Buchan River, immediately above the East Buchan Overthrust.

Buchanathyris waratahensis n.sp.

(Pl. III, figs. 5-8)

External morphology. Small, almost equally biconvex, sub-rounded shell with maximum thickness posterior of midlength. *Pedicle valve* slightly more convex than brachial valve and bearing a fairly wide, shallow sinus extending from just posterior of midlength to the anterior margin. Beak strong, incurved and bearing a circular foramen. *Brachial valve* weakly arched transversely and longitudinally. Fold indistinct. Beak short, blunt, concealed by opposite beak. Ornamentation of numerous, regularly spaced, projecting, concentric growth laminae, spaced approximately 1 mm. apart.

Internal structure. Unknown but presumed to be comparable to that of *Buchanathyris westoni.*

Types. Holotype M.U.G.D. 2083 is from the Bell Point Limestone at the north end of Bell Point, in the beds immediately underlying the *Mictophyllum-Favosites*-stromatoporoid biostrome. Paratypes are M.U.G.D. 2084 and 2085 from the Jackson's Crossing Limestone at J.C. 32, and M.U.G.D. 2150 and 2151 from the Cameron Mudstone member of the Buchan Caves Limestone at East Buchan.

Measurements. The holotype has the following dimensions: length 14·3 mm., width 13·7 mm., thickness 7·5 mm.

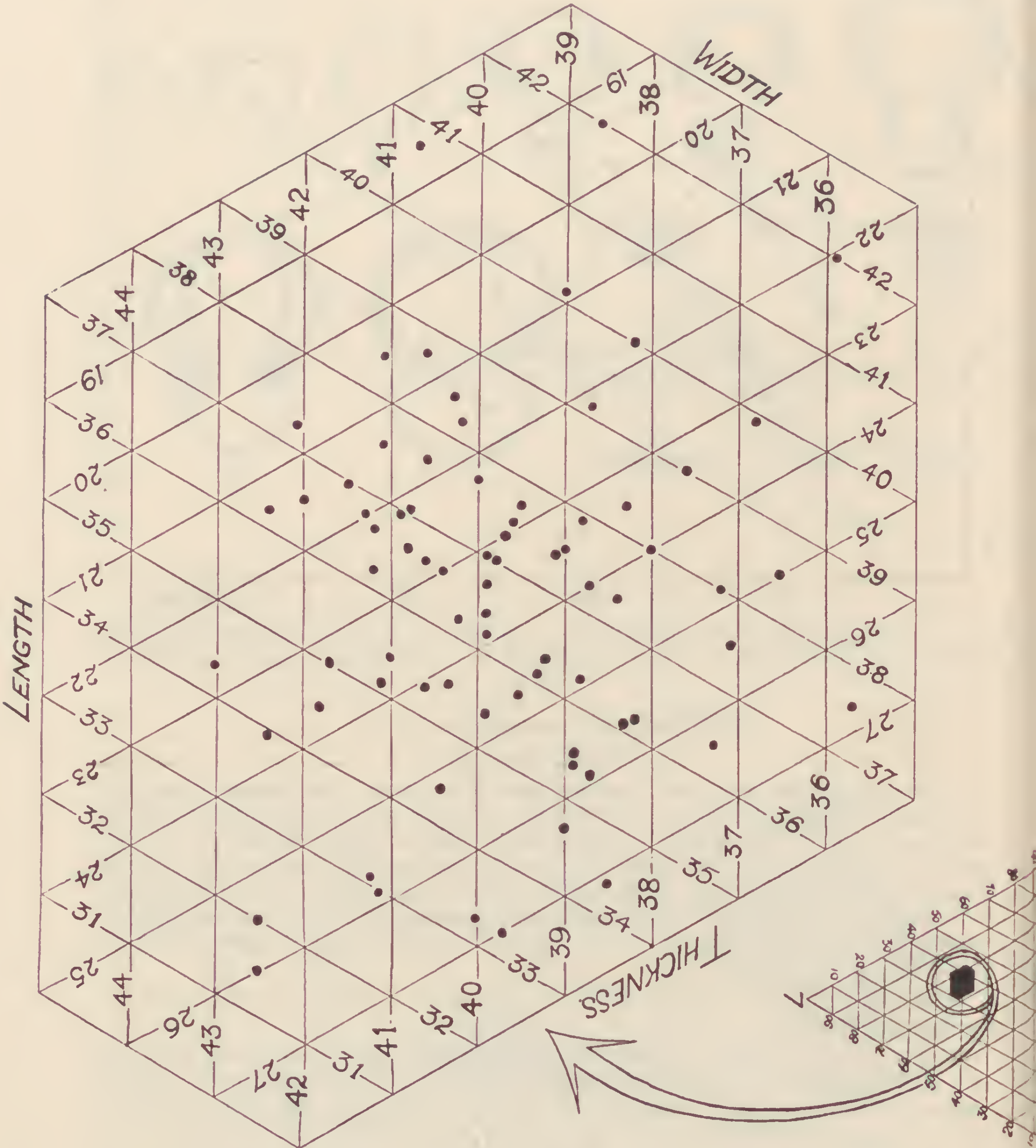


FIG. 11.—100% three-factor diagram of length, width, and thickness of 75 specimens of *Buchanathyris westoni* plotted in Fig. 10.

Discussion. *Buchanathyris waratahensis* is readily distinguished from *B. westoni* by its regularly spaced projecting lamellae. *Athyris zonulata* Stainbrook has projecting surface ornament but has a well-delineated fold on the brachial valve and is proportionately wider than *B. waratahensis.*

Buchanathyris waratahensis is found much less frequently than *B. westoni,* but is found alike in mudstones and limestones at Buchan, Jackson's Crossing, Tabberabbera, and Waratah Bay. Unlike *B. westoni* it does not appear to extend above the Buchan Caves Limestone into the Taravale Mudstone.

Superfamily PRODUCTACEA

Family CHONETIDAE Hall and Clarke, 1895

Genus **Chonetes** Fischer de Waldheim, 1837

Chonetes australis McCoy, 1876

(Pl. III, figs. 10 and 11; Fig. 12)

1876 *Chonetes australis* McCoy, Prodromus of the Palaeontology of Victoria, Decade 4, pp. 17-18, Pl. XXXV, figs. 3-5.

1951 *Chonetes australis* McCoy. Gill, Proc. Roy. Soc. Vic., Vol. 63 (N.S.), pp. 64-68, Pl. III, figs. 18-19, 21; Figs. 4-7.

External morphology. Shell of medium size, wider than long, concavo-convex, with hinge line slightly less than greatest width. Cardinal extremities obtuse angular. Anterolateral margins well rounded. *Pedicle valve* moderately and regularly convex, highest near midlength, and sloping evenly to the anterior and lateral margins and more rapidly to the hinge line. Median sinus generally absent or only incipiently developed near the anterior margin of large specimens. Umbonal region moderately convex. Beak small. Cardinal margin sharply defined and bearing four or five small, thin, hollow, conical spines approximately ·25 mm. wide at the base and 2 mm. long on either side of the beak, the spines being attached slightly oblique outwards to the cardinal margin. Palintrope low, gradually decreasing in height toward the cardinal extremities. Delthyrium triangular and closed by a strongly convex pseudodeltidium. *Brachial valve* moderately concave, deepest near midlength and curving upwards evenly to the margins, being somewhat less concave in the area enclosed by each cardinal angle. Palintrope approximately one-third as high as that of the pedicle valve. *Ornamentation* of fine rounded costellae increasing by bifurcation, about ten costellae occupying a space of 5 mm., except nearest the beak, where they are finer. A specimen 15 mm. long (21 mm. along the shell) has about 80 costellae around the margin. Lamellose growth lines rare.

Internal structure. Pedicle valve with moderately developed but strong hinge teeth. Median septum short, approximately square in cross-section, commencing near the beak and extending approximately 2 mm. along the floor of an adult specimen. Muscle scars slightly excavated, tear-shaped, and confined to the posterior third of the shell, being approximately 7 mm. long (along the shell) and 4 mm. wide at the widest point.

Brachial valve with dental sockets sharply delineated anteriorly by two posterior-marginal ridges radiating laterally from the cardinal process, these ridges being directed initially at 25° to 30° to the hinge line, then becoming deflected outwards sub-parallel to the hinge line, decreasing in angularity away from the dental sockets. Two further ridges radiating antero-laterally from the cardinal process at approximately 65° to the hinge line, the intervening space between these two ridges being

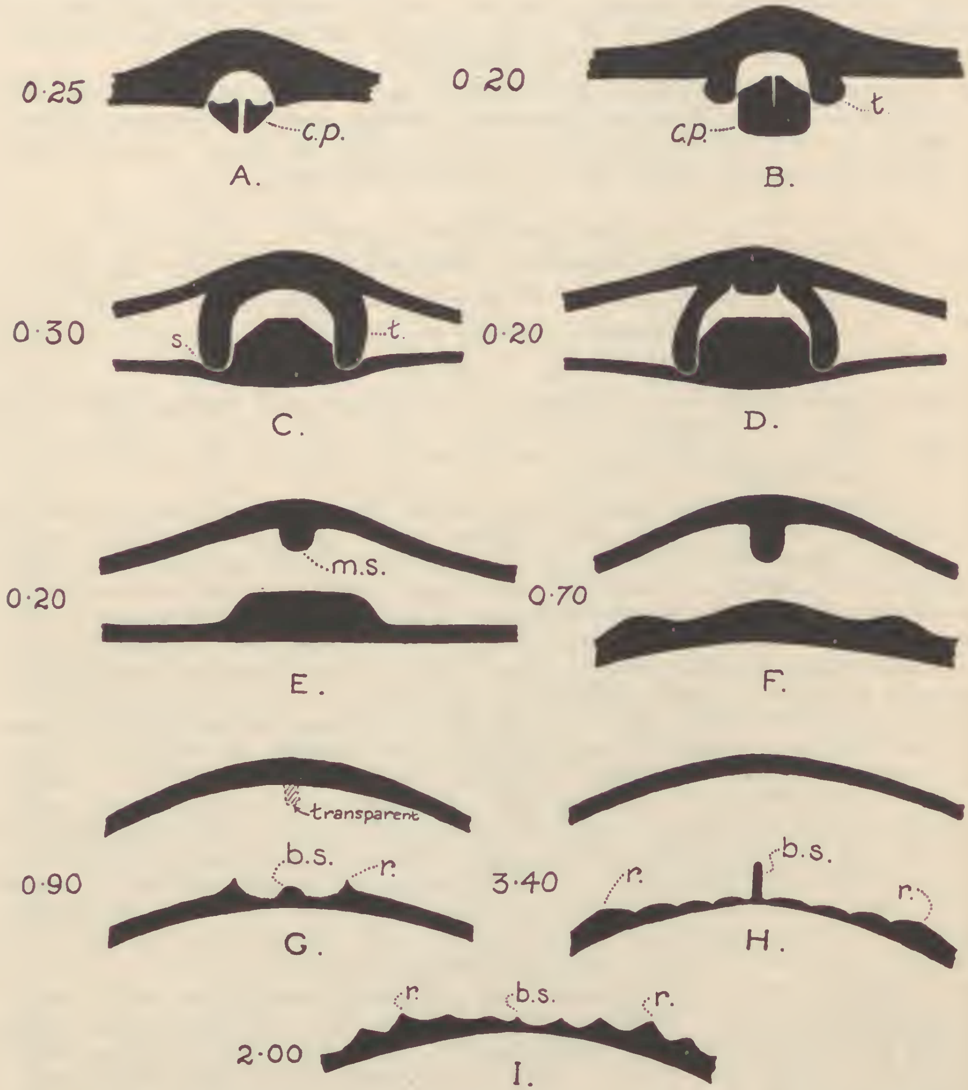


FIG. 12.—*Chonetes australis* McCoy. Series of nine successive sections, × 10, at right angles to the horizontal plane. External costellae omitted. (b.s. brachial median septum, c.p. cardinal process, m.s. pedicle median septum, r. radiating papillose costellae, t. teeth.)

subdivided by a median septum extending about 8 mm. in a mature specimen and reaching its maximum elevation at approximately three-quarters of its length away from the posterior margin. Cardinal process bifurcating into two closely approximated processes, each of which has a weakly bifid extremity. Apices of the four interspaces between the five radiating ridges occupied by four narrow tear-shaped adductor muscle scars about 1·5 to 2 mm. long and ·6 to ·8 mm. maximum width in mature specimens. Visceral disc more or less distinct and sometimes delineated by a shallow groove. Radiating, angular, papillose costellae, corresponding to grooves on the exterior, sometimes present over all the interior, or may be visible only on the belt beyond the visceral disc.

Measurements. An average specimen from Jackson's Crossing or The Basin measure 19 mm. wide, 14 mm. long, 18 mm. along the shell, and 4·7 mm. high.

Types. McCoy's types are apparently stored in the National Museum, but have not been located. Gill's hypotypes are M.D.V. 47639, 47556, 47557, M.U.G.D. 1984, N.M.V. 1513 and 1222. A slab showing weathered out interiors of brachial valves used in the above description is stored as M.U.G.D. 2185. Illustrated specimen M.U.G.D. 2183.

Discussion. Chonetes australis appears to vary in size depending on the nature of the enclosing rock. Uniformly small specimens are found in otherwise sparingly fossiliferous unctuous black calcilutite nodules of certain horizons of the Pyramids Mudstone. *C. australis* is virtually absent from the purer limestones comprising the bulk of the Buchan Caves Limestones. However, rare pockets of *C. australis* have been found from lowest fossiliferous horizons of the Buchan Caves Limestone, particularly where local muddy patches occur, through the Pyramids Mudstone where it is a characteristic fossil of black calcilutite nodules found on hillsides underlain by the Pyramids Mudstone. Largest specimens of *C. australis* are found in yellowish to pale orange calcareous mudstones and muddy limestones of the Buchan Caves Limestone and its equivalents, e.g., the mudstone outcropping in the road cutting immediately east of the first hairpin bend east of Back Creek bridge. *C. australis* is widely distributed in eastern Victoria, having been collected from Bindi, Jackson's Crossing, The Basin, Butcher's Ridge, New Guinea Point, numerous Buchan Caves Limestone localities, and all over the Pyramids Mudstone outcrops.

Gill's 1951 description and attempted elucidation of the internal structure of *C. australis* is now seen to be incomplete. The layout of ridges and median septum is different from that given by Gill in the description of the interior of an immature brachial valve. The median septum is seen to be 8 mm. and not 1 mm. long as he states. All four radiating ridges are rather strong and not occurring as traces, the anterior pair diverging at not more than 25° to the median septum. Gill, however, only mentions two minute feeble ridges diverging at 45° to the median septum.

Gill's Fig. 7 implies extension of the median septum of the pedicle valve right to the beak with fusion of septum, teeth and palintrope. However, serial sections show that the median septum does not commence until almost 1 mm. from the pedicle beak, the intervening space between the two teeth being partly filled by the cardinal process from the opposite valve. The two teeth end almost at the beginning of the median septum and likewise are not fused to the median septum of the pedicle valve. Consequently Gill's "mechanically sound structure" of a fused T-shape of palintrope and septum with teeth fused into the angles does not occur in *C. australis*.

Chonetes teicherti Gill

Chonetes teicherti Gill, 1951, Proc. Roy. Soc. Vic., Vol. 63 (N.S.), pp. 70-71, Pl. III, figs. 12-15.

This species is characteristically associated with *Chonetes australis* in the lower Pyramids Mudstone and is rarely found extending down into the Buchan Caves Limestone. Specimens have been collected up to 30 ft. below the top of the Buchan Caves Limestone.

Chonetes spooneri n.sp.

(Pl. III, fig. 9)

External morphology. Shell of large size, slightly wider than long, with hinge line apparently less than the greatest width. Cardinal extremities almost certainly obtuse. Antero-lateral margins regularly rounded. *Pedicle valve* strongly and regularly convex, highest near midlength, and sloping evenly to the anterior and lateral margins, and somewhat more rapidly in the region of the beak. Median sinus absent. Beak small. Spines unknown. Palintrope not visible but apparently very low. *Brachial valve* strongly and regularly concave, deepest near midlength and curving upwards evenly to the margins, being less concave in the area enclosed by each cardinal angle. Palintrope not seen. *Ornamentation* of rounded to subangular costellae, increasing by bifurcation, about six costellae occupying a space of 5 mm. Growth lines insignificant.

Internal structure. No substantial part of the interior of a *pedicle valve* was available for study, but an eroded valve shows that if a median septum was present it must have been necessarily short.

Brachial valve with short, deep dental sockets. Two poorly defined ridges radiating laterally from the cardinal process at approximately 30° to the hinge line, fading out approximately 8 mm. from the beak. Two further low ridges diverging posteriorly at 30° to each other (75° to the hinge line) for a distance of approximately 1 cm. from the beak, beyond this point fading out into the normal internal ornament of radiating costellae. These two ridges converge posteriorly, giving rise to an openly bilobed cardinal process, the lobes enlarging and converging posteriorly, resulting in a posterior surface of cardiform outline vertically grooved in the centre and on each lobe. Median groove running down the centre of the cardinalia, fading out approximately 5 mm. from the beak and its place being taken by a low median septum up to 0·5 mm. high and extending two-thirds of the length of the valve, thereafter being no longer distinguishable from the normal internal ornament of radiating costellae. Muscle scars poorly defined, but apparently occupying the apices of the four interspaces between the five radiating ridges. Two muscle scars occupying the medial interspaces apparently narrow, elongated, sub-tear-shaped, about 6 mm. long and 1·6 mm. at maximum width. Visceral disc not defined. Most of the interior covered by radiating papillose costellae corresponding to grooves on the exterior surface.

Measurements.

	Valve	Width (mm.)	Length (mm.)	Length along valve (mm.)
Holotype M.U.G.D. 2186 ..	Brachial	28·5	26	34
Paratype M.U.G.D. 2219 ..	Pedicle	approx. 30	approx. 28	39

Discussion. Chonetes buchanensis Gill from the lower part of the Murrindal Limestone is smaller than *C. spooneri,* tends to have wavy costellae, and has the cardinal angles relatively flattened. Unfortunately Gill was unable to describe the brachial interior of *C. buchanensis* so there is no basis for comparison of the critical features of the interior of the brachial valve. *C. baragwanathi* differs in shape and detailed structure of the interior of the brachial valve.

Chonetes buchanensis Gill

Chonetes buchanensis Gill, 1951, Proc. Roy. Soc. Vic., Vol. 63 (N.S.), pp. 68-70, Pl. III, figs. 17, 20; Fig. 8.

Fragments of specimens probably referable to *Chonetes buchanensis* have been collected from J.C. 32, but this determination is only provisional because of the poor nature of the available material.

F. Description of Pelecypods

Pelecypods are a rather subordinate element throughout the Buchan Caves Limestone and, except for a few very rare occurrences in the calcarenite phase, are limited to the almost black calcilutites characteristic of the upper part of the formation and the rare occurrences of mudstone and muddy limestone. The following forms have been determined from the calcarenites:

Cypricardinia multilamellosa n.sp.
Conocardium howitti n.sp.
Panenka sp.indet.

The uppermost 150 or 200 feet of the sequence has a much richer fauna dominated by the genus *Modiomorpha.* The following forms are described:

Modiomorpha tenuilineata n.sp.
Modiomorpha concentrirugosa n.sp.
Nuculana insolita n.sp.
Eoschizodus sp.
Leiopteria buchanensis n.sp.
Leiopteria jacksonensis n.sp.
Aviculopinna sp.indet.
Conocardium howitti n.sp.
Cornellites sp.indet.

An indeterminate specimen of *Actinopterella* has been collected from the muddy limestones of the Spooner Creek phase of the Basin Limestone. It is of interest to note the wider distribution of the *Conocardium* than other forms. They are never common but occur in calcarenites and calcilutites alike and are virtually always found in an articulated state, even when associated fossils are all disarticulated and broken and set in a matrix of shell fragments. This supports the contention that the genus *Conocardium* was a burrowing form. Unfortunately all the material was preserved in hard limestones and so prevented description of dentitions.

Family PTERINEIDAE Dall 1913, em. Maillieux, 1931

Genus **Cornellites** Williams, 1908

Cornellites, sp.ind.

Description. A single fragmentary left valve (M.U.G.D. 2197) with surface ornament of numerous sharply delineated subequidistant radial costae separated by comparatively wide interspaces and crossed by regularly spaced growth costellae

giving a somewhat reticulate appearance to the surface. Shell small, convex, with posterior wing fairly large (judging from growth lines on the remaining fragment of the posterior wing). Body directed obliquely backward. Umbo not preserved but probably markedly convex. Ventral margin with a shallow emargination in the posterior wing. Posterior wing possibly produced posteriorly in the vicinity of the cardinal margin. Ligament, interior, anterior wing, size of posterior wing, and actual size of complete specimen unknown.

Discussion. The fragment is referred to *Cornellites* rather than *Limoptera* because of the pronounced oblique nature and the conspicuous separation of the posterior wing from the body of the shell.

The incompleteness of the shell prevents complete specific identification, but it appears likely that a complete specimen would be a new species.

Genus **Actinopterella** Williams, 1908

Actinopterella sp.ind.

(Pl. III, fig. 13)

Description. Species known only from a left valve. Left valve with body directed obliquely backwards, its greatest thickness just under the beak. Posterior wing large, not distinctly separated from the body of the valve, its posterior extremity with a wide shallow emargination. Surface of left valve with about 50 costae on the body of the valve, and about 20 on the posterior wing, costae increasing by intercalation. Hinge line straight, almost as long as the shell. Umbo moderately large, probably a little elevated above the hinge line. Ventral margin obliquely rounded posteriorly, slightly concave in the region of the posterior wing. Ligament, muscle scars and teeth unknown.

Discussion. Unfortunately the only available specimen (M.U.G.D. 2199) does not show what type of dentition was present and whether the right valve was convex, flat or concave, so that specific and even generic determination must be incomplete. Consequently no attempt has been made to erect a new species. The specimen came from the Spooner Creek member of the Basin Limestone.

Family Leiopteriidae Maillieux, 1931

Genus **Leiopteria** Hall, 1883

(For diagnosis see Williams and Breger, 1916, p. 209, or La Rocque, 1950, p. 282.)

Leiopteria jacksonensis n.sp.

(Pl. III, fig. 15)

Description. Body of shell elongated ovoid, oblique at about 70 degrees to the hinge line, strongly convex. Umbo near the anterior end but not terminal. Posterior wing strongly developed, slightly concave and with a concave posterior margin. Anterior wing present, but broken, apparently very small. Ventral margin incurved below the anterior wing, obliquely rounded to the region of the posterior wing; concave near the posterior wing, ending in a sharp point at the hinge line. Hinge line straight posterior to the beak, but unknown anterior to the beak. Posterior muscular scar fairly large, subcircular, situated on the body of the shell about half way from the beak to the ventral margin. Anterior scar unknown. Dentition unknown. Ornamentation of subdued concentric growth lines of unequal thickness.

Measurements. The holotype (M.U.G.D. 2195) has the following dimensions: length along hinge line 18 mm., height along body 18 mm., thickness of left valve 4·5 mm.

Discussion. The holotype, a left valve from J.C. 54, was the only specimen available for study. *Leiopteria jacksonensis* bears no comparison with the form referred to *Leiopteria* cf. *oweni* Hall by Chapman (1908, p. 49). *L. jacksonensis* has a different shape and surface ornament from *L. cornelli* Caster, *L. peninsularis* La Rocque, *L. halli* Herrick, and *L. subplana* (Hall). Its shape conforms to that of *L. laevis* Hall, *L. rafinesquii* Hall and *L. dekayi* Hall, all typical Middle Devonian forms from North America (Onondaga to Hamilton). The last two differ in surface ornament and inclination of the body to the hinge line. *L. laevis* has a somewhat larger posterior wing and does not appear to have so convex a body in the left valve as in *L. jacksonensis.* The European species can likewise all be separated from *L. jacksonensis. L. jacksonensis* is without the very deep concavity in the posterior wing seen in *L. crenatolamellosa* (G. and F. Sandberger) and has a more strongly arched body than *L. pseudolaevis* (Oehlert), *L. globosa* Spreistersbach and *L. kerfornei* (Oehlert). *L. subcrenata* (de Koninck), *L. concentrica* (Roemer) and *L. pseudolamellosa* Mauz can likewise be separated on consideration of surface ornament, body convexity, and the shape of the posterior wing. Of all the species known to the author the greatest similarity is to *Leiopteria laevis* Hall from the Onondaga and Marcellus of the United States. This comparison lends some support to the Middle Devonian age of the Buchan Caves Limestone.

Leiopteria buchanensis n.sp.

(Pl. III, fig. 14; Pl. IV, fig. 8)

Description. Body of shell elongated ovoid, oblique at about 75 degrees to the hinge line. Shell large for the genus, biconvex, with left valve more strongly convex than the right. Umbo near the anterior wing but not terminal. Posterior wing strongly developed, slightly concave and with a very slightly concave posterior margin. Anterior wing small. Ventral margin obliquely rounded to the posterior wing. Hinge line straight posterior to the beak, but directed slightly downward in front of it. Posterior muscular scar faintly visible in a right valve, large, broadly oval, situated entirely on the body of the shell approximately half way to the ventral margin. Anterior scar and ligament unknown. Dentition unknown. Ornamentation of fairly strong concentric growth lines.

Measurements. All available material is incomplete in varying degrees, so the following dimensions of the holotype are somewhat approximate: Length along hinge line 40 mm., height 40 mm., thickness of both valves 21 mm., thickness of left valve 13 mm. These are rather typical measurements, as all fragments so far collected are of the order of 40 mm. in either direction.

Types. Holotype M.U.G.D. 2191 from R.C.R. 29; paratypes M.U.G.D. 2194, 2201 from R.C.R. 29 and M.Rd. 92; M.U.G.D. 2193, a right valve, is a figured specimen.

Discussion. Leiopteria buchanensis is rather similar to *Leiopteria jacksonensis* described above. However, most specimens so far collected are much larger (two to three times as large), are more subquadrate in appearance, and have the posterior wing slightly less sharply delineated from the body. The posterior wing is less concave posteriorly and consequently less sharply produced at the hinge line. Comparisons given above for *L. jacksonensis* with European and North American species of *Leiopteria* hold for *L. buchanensis.*

Family Modiolopsidae Fischer em. Dall

Genus **Modiomorpha** Hall

Modiomorpha tenuilineata n.sp.

(Pl. IV, figs. 3-6)

Description. Shell equivalve, or nearly so, longer than wide, directed obliquely backward. Hinge line straight, almost as long as the shell. Umbones relatively large, distinctly raised above the hinge line, situated within the anterior third of the shell, but not terminal; curving slightly forward. Anterior margin evenly rounded; posterior margin broadly rounded ventrally and obliquely rounded to the hinge line. External ligamental groove elongated. Surface with numerous fine low concentric lines, waxing and waning, but generally stronger near the anterior end. Occasionally showing a faintest trace of radial ornament. Interior unknown. Shell material thin and black.

Measurements. The holotype has the following dimensions: Inferred length 34 mm., height 19·3 mm., thickness 14·7 mm. A right valve paratype has a length of 34 mm. and a height of 17·5 mm.

Types. Holotype M.U.G.D. 2188 from M.G. 26; paratypes M.U.G.D. 2189 from J.C. 55; 2203, 2204 and 2205 from J.C. 56.

Discussion. Modiomorpha tenuilineata is erected for the smoother types of *Modiomorpha* characteristic of the upper part of the Buchan Caves Limestone. *M. concentrirugosa* described below covers generally larger forms with concentric rugae.

Modiomorpha concentrirugosa n.sp.

(Pl. IV, figs. 1, 2)

Description. Shell subequivalve, longer than wide, directed obliquely backward. Hinge line long, straight. Umbones raised above the hinge line, situated within the anterior third of the shell. Anterior margin evenly rounded; posterior margin straight to slightly concave ventrally, broadly rounded posteriorly. Ligament not seen on any available material. Anterior muscular scar small, almost round; posterior scar larger, shallow, sub-rounded, situated near the posterior margin. Dentition unknown. Surface ornamented by waxing and waning concentric rugae more strongly pronounced at the anterior end.

Measurements. The holotype has the following dimensions: Inferred length 45 mm., height 22 mm., inferred thickness 20 mm.

Types. Holotype M.U.G.D. 2187; paratypes M.U.G.D. 2209 and 2210 from R.S.M. 67; 2211, 2212 and 2213 from S.R. 51; M.U.G.D. 2214 and 2215 from R.S.M. 69.

Family Ledidae Adams

Genus **Nuculana** Link, 1807 (= **Leda** Schumacher, 1817)

Nuculana insolita n.sp.

(Pl. IV, fig. 9)

Description. Nuculoid pelecypod of moderate size with extended posterior margin. Cardinal margin strongly rounded anteriorly and continuous with the anterior margin; anterior margin curving evenly to give a gently convex ventral margin. Cardinal margin concave posteriorly and continuous with the extended upwardly deflected posterior margin. Posterior margin gaping at its truncated termination.

Beaks small, posteriorly directed. Posterior umbonal ridge concave upwards. Surface apparently smooth. Escutcheon elongate. Musculature imperfectly preserved. A slight change in proportional length occurring during growth, youthful stages being relatively shorter than adult specimens. Posterior siphonal portion of shell proportionately more slender in adults than in juveniles.

Measurements. The holotype has the following dimensions: Length 18·8 mm., height 8 mm.; thickness of both valves would be about 4·5 or 5 mm.

Type. Holotype M.U.G.D. 2192 from R.S.M. 67.

Discussion. Nuculana insolita differs from the other representatives of this long ranging genus in the virtual absence of concentric growth striations and in the shape of the posterior siphonal portion of the shell. Next to the species of *Modiomorpha, N. insolita* is the most common pelecypod of the upper Buchan Caves Limestone.

Family PINNIDAE Gray

Genus **Aviculopinna** Meek, 1864

Aviculopinna sp.indet.

(Fig. 13)

A fragmentary left valve (M.U.G.D. 2198) from R.S.M. 66 apparently belongs to *Aviculopinna*. Shell greatly elongated, acutely triangular, with a long hinge line. Surface marked by strong, regular, concentric growth lines. Beak inferred to be

FIG. 13.—*Aviculopinna* sp.indet. Drawing of M.U.G.D. 2198 from R.S.M. 66.

almost terminal. Ventral margin almost straight but very slightly convex; posterior margin broadly rounded and meeting the hinge line almost at a right angle.

This appears to be the only pre-Carboniferous record of *Aviculopinna* or any closely allied form with this type of surface ornament. *Palaeopinna* Hall from the Devonian has radiating surface ornament.

Family MYOPHORIIDAE

Genus **Eoschizodus** Cox, 1951

Eoschizodus sp.indet.

(Fig. 14)

Description. Medium-sized trigonal shell of moderate convexity, having a short, arcuate cardinal margin, a circular anterior margin abruptly deflected to the obliquely truncate, slightly convex, posterior margin. Umbones high with beaks pointed, incurved, slightly opisthogyre. Prominent umbonal ridge dividing the shell into

FIG. 14.—*Eoschizodus* sp.indet. Draw- of M.U.G.D. 2196 from M.G. 38, showing internal cast (white), and fragment of external ornament in lower left corner of drawing.

an anterior convex region and a posterior flattened region. Ornamentation of low concentric undulations on exterior of shell only. Dentition unknown. Posterior muscle scar of moderate size bounded by a groove at its anterior margins, the groove broadening ventrally. Anterior muscle scar unknown.

Measurements. The figured specimen (M.U.G.D. 2196), a right valve from M.G. 38, has a length of 23 mm., height 18 mm., thickness 4·5 mm.

Family PLEUROPHORIDAE Dall

Genus **Cypricardinia** Hall, 1859

Cypricardinia multilamellosa n.sp.

(Pl. IV, fig. 7)

Description. Shell known only from a right valve, longer than wide, evenly convex, with maximum height well posterior of the beak. Umbo raised above the hinge line, incurved, situated in the posterior third of the shell. Anterior margin broadly rounded; posterior margin slightly convex ventrally in a broad sweep, then probably broadly rounded to the hinge line. Ligament and interior unknown. Surface ornamented by evenly spaced sharp concentric rugae, almost assuming the appearance of projecting laminae. Interspaces between the coarse ornament occupied by concentric growth lines.

Measurements (inferred). Length 70 mm., height 40 mm., height of right valve 10 mm.

Types. A single right valve from M.Rd. 33 is the holotype, M.U.G.D. 2190a and M.U.G.D. 2190b counterparts. Paratype is a right valve, M.D.V. 47498, from Teichert's locality 27.

Family Conocardiidae Neumayr

Genus **Conocardium** Bronn, 1834

Conocardium howitti, n.sp.

(Fig. 8)

Conocardium cf. *Sowerbyi* de Koninck. Chapman, 1912, Rec. Geol. Surv. Vic., Vol. 3, Pt. 2, p. 220.

Description. Shell small, alate, gibbous. Beak acute, fairly strongly incurved over the hinge and slightly oblique towards the posterior. Anterior wing delineated by an increase in density of the radial ribs, two very close ribs marking the margin. Anterior wing bearing six angular ribs near the hinge, increasing by intercalation to eight further out. These ribs separated by much wider interspaces and confined to the posterior two-thirds of the anterior wing, the anterior third bearing only the concentric growth lamellae. Body inflated, posteriorly oblique, subcircular in section, marked by three strong angular ribs and four much wider interspaces, the most posterior of these being occupied by three or four more angular but much weaker ribs inserted away from the beak. Posterior region truncate, oblique at 45° to the

Fig. 15.—*Conocardium howitti.* Drawing of holotype M.U.G.D. 2200 from the Buchan Caves Limestone at M.Rd. 74, showing "ribbing" (actually internal grooves) and broken away portions as black. Note the concentric "lamellae" on the anterior wing, representing projections of shell material into the visceral cavity.

vertical axis and marked by eight flat, rounded, curving ribs separated by sharp, narrow grooves. Three of these eight ribs formed by branching of the first rib delimiting the posterior region. Growth lines consisting of regularly spaced lamellae set at right angles to the surface, about 0·1 mm. apart, and 0·03 mm. in width.

Measurements. Holotype has a length of 5 mm., height 4 mm.; thickness of right valve approximately 2 mm.

Types. Holotype M.U.G.D. 2200 from M.Rd. 74; paratype M.U.G.D. 2218 from R.C.R. 28, showing relatively smooth interior.

Discussion. Casts and decorticated specimens show that the exterior of the shell was comparatively smooth, as Branson (1942, Card 28) suggests is the case for all species of *Conocardium*. The nearest described species is *Conocardium bellulum* Cresswell. *Conocardium sowerbyi* de Koninck in some degree approximates the new species *C. howitti* which, however, differs in detail of ribbing and number of ribs, and is much smaller than the neotype of *C. sowerbyi* or the other measured specimen mentioned by Fletcher (1948, p. 236).

Distribution. *Conocardium howitti* is the most widely distributed pelecypod at Buchan. It has been collected from R.S.M. 64, 65, 76 and 77, R.C.R. 26, M.Rd. 69 and 74, and from the Butcher's Ridge Limestone.

Family PRAECARDIIDAE Neumayr

Genus **Panenka** Barrande, 1881

Panenka sp.indet.

Description. A single fragmentary specimen of a *Panenka* has been collected from coarse mid grey calcarenite outcropping beside the Caves Road, about 70 yards north of the entrance to the Royal Cave. Unfortunately the specimen is too incomplete to warrant description.

G. List of Cited Localities

Gill. Stratigraphic section through the Gillingall Limestone, E. side of Woolshed Creek, opposite the old Gillingall homestead. Distances in feet stratigraphically above the Snowy River Volcanics outcropping in Woolshed Creek.

- 3 Chocolate brown tuffaceous limestone weathering dull yellow, 31′.
- 6 About 3′ of silicified rhyolitic tuff, 88′.

J.C. Stratigraphic section through the Jackson's Crossing Limestone from the base of Davidson's Cliff, Jackson's Crossing. Distances are in feet stratigraphically above the base of the cliff.

- 27 Almost black calcilutite with *Tentaculites*, 250′.
- 32 Richly fossiliferous muddy limestone, 304′.
- 34 Calcareous mudstone with rare nodules, 350′.
- 35 Richly fossiliferous thin nodular limestone, 365′.
- 39 Finely laminated limestone, 392′.
- 43 Ostracodal limestone, 414′.
- 46 Band with *Spinella buchanensis scissura*, 447′.
- 54 Almost black calcilutite with abundant pelecypods and *Spinella*, 563′.
- 55 Similar to 54 with occasional nautiloids and rugose corals, 573′.
- 56 Similar to 55 with abundant ostracodes, 578′.

M.G. Stratigraphic section up McLarty's Gully, Buchan Caves Limestone, from the Murrindal River. Distances are in feet stratigraphically above the level of the river.

- 14 5′ thick band of dark grey calcarenite characterized by abundant *Buchanathyris*, *Loxonema* and *Spinella* infilled by white crystalline calcite, 252′.
- 16 Similar band to 14, 291′.
- 26 Very fine-grained calcarenite (or calcilutite) with *Spinella*, *Modiomorpha* and ostracodes, 382′.
- 38 Dark grey to black fine-grained calcarenite with fairly abundant brachiopods and less common *Breviphyllum*, *Eoschizodus* and ostracodes.

M.Rd. Stratigraphic section through the Buchan Caves Limestone three-quarters of a mile N.N.W. of the end of Moon's Rd., Buchan. Distances are in feet stratigraphically above the Snowy River Volcanics.

1 Thin basal grit.
33 Detrital calcarenite with abundant brachiopods and occasional *Favosites*, *Breviphyllum* and *Cypricardinia*, 300′.
43 Coarse unfossiliferous calcarenite, 393′
64 Richly fossiliferous band with abundant *Breviphyllum*, and occasional *Syringopora*, *Loxonema*, *Spinella*, *Buchanathyris*, 520′.
68 Yellow to buff earthy calcarenite with abundant brachiopods, *Loxonema*, *Straparolus*, *Breviphyllum*, etc., 551′.
74 Pale grey calcarenite with *Conocardium* and *Breviphyllum*, 622′.
92 Almost black ostracodal limestone alternating with black calcilutites containing *Spinella* and small pelecypods, 750′.

R.C.R. Stratigraphic section up Rocky Camp Ridge from the base of the Buchan Caves Limestone exposed in the Murrindal River. Distances are in feet stratigraphically from the base.

28 Dark grey stylolitic calcarenite with occasional *Spinella*, *Conocardium* and ostracodes, 492′.
29 Slightly muddy calcilutite with abundant *Spinella* and pelecypods including *Modiomorpha*, 500′.

R.S.M. Stratigraphic section up the prominent ridge one-third of a mile S. of Murrindal, through the Buchan Caves Limestone. Distances are in feet from the top of the Snowy River Volcanics.

12 Dark grey calcarenite with rare fine *Receptaculites*, 141′.
66 Almost black calcilutite with abundant nautiloids, *Spinella* and algae, and less common *Nuculana* and *Modiomorpha*, 548′.
67 Almost black ostracodal limestone with abundant *Spinella* and common pelecypods, 551′.
69 Same as 67, 566′.
77 Mid grey stylolitic fine-grained calcarenite with crinoid stems, *Loxonema*, *Uncinulus*, *Chonetes australis*, and *Howittia howitti*, 653′.
78 Dark grey calcarenite with small crinoid stems and a phacopid trilobite pygidium, 658′.

S.R. Stratigraphic section up the prominent ridge three-quarters of a mile S. of Murrindal, through the Buchan Caves Limestone. Distances are in feet stratigraphicallly from the approximate position of the top of the Snowy River Volcanics.

51 Black calcilutite teeming with *Spinella*, ostracodes, and pelecypods (*Modiomorpha*, *Nuculana*, and *Eoschizodus*), 580′.
52 Similar to 51, 600′.

H. Cited Literature

Allan, R. S., 1947. A Revision of the Brachiopoda of the Lower Devonian Strata of Reefton, New Zealand. *Jour. Paleontology*, XXI; 436-452, pls. lxi-lxiii.

Branson, C. C., 1942. Conocardiidae (Unit 5B) in Type Invertebrate Fossils of North America (Devonian). *Wagner Free Inst. Sci.*, 30 cards.

Chapman, F., 1905. New or Little-known Victorian Fossils in the National Museum, Melbourne, Part 6, Notes on Devonian Spirifers. *Proc. Roy. Soc. Vic.*, XVIII (N.S.); 16-19, pl. v.

———, 1917. Preliminary Notes on New Species of Silurian and Devonian Fossils from North-East Gippsland. *Rec. Geol. Surv. Victoria*, IV; 103-104.

———, 1920. Palaeozoic Fossils of Eastern Victoria. Part IV. *Rec. Geol. Surv. Vic.*, IV; 175-194, pls. xvi-xxxii.

Cloud, P. E., Jr., and Barnes, V. E., 1948. The Ellenburger Group of Central Texas. *Univ. Texas Bur. Econ. Geol.*, Pub. 4621.

Crickmay, C. H., 1950. Some Devonian Spiriferidae from Alberta. *Jour. Paleont.*, XXIV; 219-225, pls. xxxvi-xxxvii.

DEFORD, R. K., 1946. Grain Size in Carbonate Rock. *Am. Assoc. Petrol. Geologists Bull.*, XXX; 1921-1928.

FLETCHER, H. O., 1943. The Genus *Conocardium* from Australian Palaeozoic Rocks. *Rec. Aus. Mus.*, XXI; 231-243, pls. xiii-xiv.

GILL, E. D., 1951. Further Studies in Chonetidae (Palaeozoic Brachiopoda) from Victoria. *Proc. Roy. Soc. Vic.*, 63 (N.S.); 57-72, pl. iii.

GRABAU, A. W., 1931. Devonian Brachiopoda of China. Part I. Devonian Brachiopoda from Yunnan and Other Districts of South China. *Palaeontologia Sinica*, Series B, III, Fasc. 3; 1-545, pls. i-liv.

HILL, D., 1950. Middle Devonian Corals from the Buchan District, Victoria. *Proc. Roy. Soc. Vic.*, 62 (N.S.); 137-164, pls. v-ix.

HOWITT, A. W., 1876. Notes on the Devonian Rocks of Northern Gippsland. *Geol. Surv. Vic., Rep. Progr.*, No. 3; 181-249.

———, 1878. Notes on the Devonian Rocks of Northern Gippsland. *Geol. Surv. Vic., Rep. Progr.*, No. 5; 117-136.

JOHNSON, J. H., 1942. Permian Lime-Secreting Algae from the Guadalupe Mountains, New Mexico. *Bull. Geol. Soc. Am.*, LIII; 195-226.

KROMMELBEIN, K., 1954. Devonische Ostracoden aus der Gegend von Buchan und von der Küste der Waratah Bay, Victoria, Australien. *Senckenbergiana*, Bd. 35, Nr. 3/4, 119-229, Taf. 1-5.

LA ROCQUE, A., 1950. Pre-Traverse Devonian Pelecypods of Michigan. *Contrib. Mus. Paleont., Univ. of Michigan*, VII (10); 271-366, 19 pls.

McCOY, F., 1876. Prodromus of the Palaeontology of Victoria, Decade 4.

MAILLIEUX, E., 1910. Première Note sur les Spirifères. *Bull. Soc. belge de Géol.*, XXIV; 322-376.

———, 1931. La Faune des Grès et Schistes de Solières (Siegenien Moyen). *Mem. Mus. Roy. d'Hist. Nat. de Belgique*, LI; 1-90, pls. i-ii.

———, 1936. La Faune et l'âge des Quartzophyllades Siegeniens de Longlier. *Mem. Mus. Roy. d'Hist. Nat. de Belgique*, LXXIII; 1-141, i-iii.

———, 1937. Les Lamellibranches du Devonien Inférieur de L'Ardenne. *Mem. Mus. Roy. d'Hist. Nat. de Belgique*, LXXXI; 1-273, i-xiv.

NEWELL, N. D., RIGBY, J. K., FISCHER, A. G., WHITEMAN, A. J., HICKOX, J. E., and BRADLEY, J. S., 1953. The Permian Reef Complex of the Guadalupe Mountains Region, Texas and New Mexico. (W. H. Freeman & Co., San Francisco.)

NOMURA, A., and HATAI, K., 1936. A Short Note on the Shells of Certain Invertebrates. *Saito Ho-on Kai Mus. Res. Bull.*, No. 10; 212-217.

———, 1936. A Note Concerning Data on the Bathymetric Range of Certain Marine Animals, etc. *Saito Ho-on Kai Mus. Res. Bull.*, No. 10; 231-334.

PIA, J. V., 1940. Vorläufige Ubersicht der Kalgalgen des Perms von Nord-amerika. *Akad. Wiss. Wien, Math. Naturwiss. Kl.*, Anz. 9, preprint, June 13.

RIPPER, E. A., 1937. On the Stromatoporoids of the Buchan District, Victoria. *Proc. Roy. Soc. Vic.*, 50 (N.S.); 11-38, pls. ii-v.

RUEDEMANN, R., 1897. Evidence of Current Action in the Ordovician of New York. *Am. Geol.*, XIX; 367-391.

———, 1898. Additional Note on the Oceanic Current in the Utica Epoch. *Am. Geol.*, XXI; 75-81.

———, 1929. Coralline Algae, Guadalupe Mountains. *Bull. Amer. Assoc. Petrol. Geol.*, XIII; 1-154.

STAINBROOK, M. A., 1943. Spiriferacea of the Cedar Valley Limestone of Iowa. *Jour. Paleont.*, XVII; 417-450, pls. lxv-lxx.

TEICHERT, C., 1948. Middle Devonian Goniatites from the Buchan District, Victoria. *Jour. Paleont.*, XXII; 60-67, pl. xvi.

———. Unpublished Report and Map of Buchan Area. Mines Department of Victoria.

——— and GLENISTER, B. F., 1952. Fossil Nautiloid Faunas from Australia. *Jour. Paleont.*, XXVI; 730-752, pls. civ-cviii.

TERZAGHI, R. D., 1940. Compaction of Lime Mud as a Cause of Secondary Structure. *Jour. Sed. Petrol.*, X; 78-90.

WAGNER, G., 1913. Stylolithen und Drucksuturen. *Geol. Paleont.*, Abh. (N.S.), II (15), No. 2.

WOOD, A., 1948. "Sphaerocodium". A Misinterpreted Fossil from the Wenlock Limestone. *Proc. Geologists' Assoc.*, LIX; 9-22, pls. ii-v.

Explanation of Plates

Plate I

Figs. 1-5.—*Spinella buchanensis buchanensis* n.gen., n.sp., n.subsp. 1, 2, 4, 5.—Pedicle, brachial, anterior and posterior views × 1·3 of holotype M.U.G.D. 2152 from the base of the Pyramids Mudstone, road cutting immediately south of Murrindal State School. 3.—Exterior enlarged × 7 to show characteristic surface ornament of fine spines.

Figs. 6, 7.—*Spinella buchanensis scissura* n.gen., n.sp., n.subsp. Brachial and pedicle views of holotype M.U.G.D. 2153, × 1·3. Specimen from Buchan Caves Limestone at M.G. 31.

Fig. 8.—*Spinella maga* n.gen., n.sp. Posterior view × 1·3 of holotype M.U.G.D. 2154 from the upper part of the Buchan Caves Limestone, Murrindal.

Plate II

Figs. 1-3, 11, 12.—*Spinella buchanensis philipi* n.gen., n.sp., n.subsp. 1-3.—Brachial, anterior and posterior views of a paratype M.U.G.D. 2155. 11, 12.—Anterior and posterior views of holotype M.U.G.D. 2156. Both specimens from the Cameron Mudstone Member of the Buchan Caves Limestone. Figs. 1-3 are × 1, figs. 11 and 12 × 1·3.

Figs. 4-7.—*Spinella buchanensis buchanensis* n.gen., n.sp., n.subsp. Pedicle, brachial, anterior and lateral views of flatter-ribbed specimen M.U.G.D. 2157 from R.C.R. 29 tending towards *Spinella buchanensis scissura.*

Figs. 8-10.—*Spinella buchanensis buchanensis* n.gen., n.sp., n.subsp. Brachial, lateral, and posterior views of more angular-ribbed specimen M.U.G.D. 2158. Views are × 2, × 1, and × 1·5 respectively.

Figs. 13-17.—*Howittia howitti* (Chapman) n.gen. 13-16.—Brachial, pedicle, and anterior views of hypotype M.U.G.D. 2159, × 1·5. 17.—Pedicle view of hypotype M.U.G.D. 2160, × 1. Both specimens from base of Pyramids Mudstone, cutting immediately south of Murrindal State School.

Plate III

Figs. 1-4.—*Buchanathyris westoni* n.gen., n.sp. 1-3.—Pedicle, brachial and posterior views × 1·6 approx. of holotype (M.U.G.D. 2184) from low in the Taravale Mudstone, approximately 200 yards inside the entrance gate to the Caves Reserve, Buchan. 4.—View × 1·6 of interior of pedicle valve of paratype (M.U.G.D. 2312) from same locality as holotype, showing thick dental lamellae.

Figs. 5-8.—*Buchanathyris waratahensis* n.gen., n.sp. 5, 6.—Pedicle and brachial views × 3 of holotype (M.U.G.D. 2083) from north end of Bell Point, Waratah Bay, Victoria. 7, 8.—Pedicle and brachial views of paratype (M.U.G.D. 2085) from Jackson's Crossing Limestone at J.C. 32.

Fig. 9.—*Chonetes spooneri* n.sp. Brachial valve × 1·3 of holotype from Spooner Creek muddy phase of the Basin Limestone.

Figs. 10, 11.—*Chonetes australis* McCoy. Pedicle and brachial views × 1·2 and × 1 respectively of hypotype M.U.G.D. 2183 from Jackson's Crossing Limestone at J.C. 32.

Fig. 12.—*Leiopteria* sp.indet. Side view × 1·1 of specimen M.U.G.D. 2193 from Buchan Caves Limestone at R.C.R. 29.

Fig. 13.—*Actinopterella* sp.indet. Side view × 1 of left valve specimen M.U.G.D. 2199 from Spooner Creek muddy phase of the Basin Limestone.

Fig. 14.—*Leiopteria buchanensis* n.sp. Side view × 1 of left valve paratype M.U.G.D. 2194 from Buchan Caves Limestone at M.G. 38.

Fig. 15.—*Leiopteria jacksonensis* n.sp. Side view × 1 of left valve holotype M.U.G.D. 2195 from Jackson's Crossing Limestone at J.C. 53.

Plate IV

Figs. 1, 2.—*Modiomorpha concentrirugosa* n.sp. Side view of right and left valves respectively of holotype M.U.G.D. 2187, × 1, from the Buchan Caves Limestone at S.R. 53.

Figs. 3-6.—*Modiomorpha tenuilineata* n.sp. 3-5.—Side views of right and left valves respectively and dorsal view of holotype M.U.G.D. 2188, × 1·1, from Buchan Caves Limestone, M.G. 26. 6.—Side view of right valve paratype M.U.G.D. 2189, × 1, from the Jackson's Crossing Limestone at J.C. 55.

Fig. 7.—*Cypricardinia multilamellosa* n.sp. Side view of left valve holotype M.U.G.D. 2190, × 1, from the Buchan Caves Limestone at M.Rd. 33.

Fig. 8.—*Leiopteria buchanensis* n.sp. Side view of left valve holotype M.U.G.D. 2191, × 1, from the Buchan Caves Limestone at R.C.R. 29.

Fig. 9.—*Nuculana insolita* n.sp. Side view of right valve holotype M.U.G.D. 2192, × 2, from the Buchan Caves Limestone at R.S.M. 67.

PLATE V

Fig. 1.—Coarse-grained calcarenite (lime-sandstone), photomicrograph, × 10 approx., M.Rd. 43, 393 ft. stratigraphically above base of Buchan Caves Limestone. Calcite has recrystallized.

Fig. 2.—Partly detrital calcarenite (lime-sandstone), photomicrograph, × 7 approx., M.Rd. 33, 300 ft. stratigraphically above base of Buchan Caves Limestone. Dark grains of detrital calcite and other bioclastic debris in a matrix of clear calcite. The two fragments of *Spinella* shell show differing degrees of abrasion of plications.

Fig. 3.—Calcilutite (lime-mudstone), photomicrograph, × 30, R.S.M. 69, 566 ft. stratigraphically above base of Buchan Caves Limestone. Section has a very high proportion of organic matter. Fine jagged margin of *Spinella* shell is resultant from attack by penetrative algae (seen only under high power).

Fig. 4.—Silicified rhyolitic tuff, photomicrograph, × 30, Gill. 6, 88 ft. stratigraphically above level of Woolshed Creek, Gillingall, Gillingall Limestone.

Fig. 5.—Laminated limestone, photomicrograph, × 10, J.C. 39, 392 ft. stratigraphically above base of Davidson's Cliff, Jackson's Crossing, Jackson's Crossing Limestone. Expansion to the right is around a small algal pisolith with a shell fragment as core. Pisolith not shown.

Fig. 6.—Algal pisolite, photomicrograph, × 10, M.Rd. 51, 474 ft. stratigraphically above base of Buchan Caves Limestone. Section shows parts of two pisoliths, each composed of two different types of algal structure. Between the pisoliths is a small *Anematina* (oblique section) and clear calcite. Some algae have grown inside the *Anematina*.